JOURNAL OF THE A·I·E·E·

DECEMBER 1924

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

American Institute of Electrical Engineers

COMING MEETINGS

Midwinter Convention, New York, N. Y., February 9-12

MEETINGS OF OTHER SOCIETIES

Georgia Electrical Association—East Lake Country Club, Atlanta, Nov. 26

American Society of Refrigerating Engineers—New York, Dec. 1-3

American Society of Mechanical Engineers—New York, Dec. 1-4

Empire State Gas & Electric Association, Electric Division—Syracuse, Dec. 4-5

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Institute and Related Activities—*Continued.*

Current Electrical Articles Published by Other Societies

Bulletin, Minnesota Federation of Arch. and Engng. Society, October, 1924
Utilization of Electrical Energy on the Farm, by H. E. Young

Iron and Steel Engineer, October, 1924
Electrification of Tata Iron Works at Jamshedpur, India, by S. Ghosh

Journal American Welding Society, September, 1924
Electric Spot Welding Aluminum or Duralimin, by J. W. Meadowcroft

Journal American Welding Society, October, 1924
Use of Electric Arc for Welding Structural Steel, by R. E. Kinkead

Journal Franklin Institute, October, 1924
Minimal Length Arc Characteristics, by H. E. Ives

Journal Western Society of Engineers, September, 1924
Recent Advances in Hydroelectric Engineering Practise, by L. F. Harza
Slow Speed Locomotives for Coal Mines, by S. W. Farnham

National Electric Light Association Bulletin, October, 1924
Shall We Electrify Agriculture? by P. O. Davis
State Versus Private Ownership of Electrical Utilities, by A. T. Hadley

Physical Review, October, 1924
Ionizing Potentials of Multiatomic Gases, by C. A. Mackay
An Electrometer Method for Measuring Dielectric Constants of Liquids, by A. P. Carman

Proceedings American Society of Civil Engineers, October, 1924
Interconnected Power Systems of the Southeast, by C. G. Adsit

Proceedings Institute Radio Engineers, October, 1924
Transmitting Equipment Radio Telephone Broadcasting, by E. L. Nelson
Method of Measuring Radio Field Intensities and Atmospheric Disturbances, by L. W. Austin and E. B. Judson
An Analysis of Two Triode Circuits, by J. H. Morecroft and A. G. Jenson
Transmitting Equipment for Radio Telephone Broadcasting, by E. L. Nelson
Experimental Determination of the Fundamental Dynamic Characteristics of a Triode, by E. Takagishi
High Efficiency Vacuum Tube Oscillating Circuit, by D. C. Prince and F. B. Vogdes

Trans. Illuminating Engineering Society, October, 1924
Report of Committee on Automobile Headlights—International Commission on Illumination, by C. H. Sharp
Year's Progress in Illumination, 1923-1924

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Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

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National and District Meetings Discussed by M. and P. Committee

At a session of the Meetings and Papers Committee held November 14th at Institute Headquarters a number of important matters was discussed. These included the coming Midwinter, Spring and Annual Conventions, district or regional meetings, and the relation of Technical Committees to Standards work.

Plans for the coming conventions were settled as definitely as possible. The list of papers for the Midwinter Convention was practically decided upon and these are published elsewhere in this issue. The Spring Convention program, which will be presented in St. Louis probably the week of April 13th, was outlined and such subjects as power-plant design and industrial applications are included in the preliminary plans. January 15th will be the last day for the receipt of papers for this meeting.

The Annual Convention in the latter part of June will probably be held in the eastern part of the country, though it has not yet been possible to set a definite location.

The committee adopted a recommended plan for regional meetings which will be submitted to the Board of Directors in answer to a request by them. This plan suggests an organization within the District intended for conducting a regional meeting and handling other matters and also suggests certain working rules. It was reported at this meeting that regional meetings are contemplated during the present fiscal year in two geographical districts. These are District No. 1 and District No. 2. In the latter, two such meetings may be held, one in the eastern part and another in the western part.

H. S. Osborne, Chairman of the Standards Committee, sketched the organization and operation of that Committee and its components, and outlined the functions of the Technical Committees in connection with the preparation and revision of standards.

Who Will Interpret the Code?

The National Electric Code, long the authority regulating electric wiring and electric installation, is the product of periodical meetings of the Electrical Committee of the National Fire Protection Association.

The provisions of the Code are administered throughout the country by State Wiring Inspectors, City Electrical Departments and in some instances by Insurance Underwriters' Inspectors.

In the main, the Code has served its purpose very well, although at times there has been resentment against its application by inspectors, the resentment originating with electrical contractors, manufacturers of electric devices, or owners of electric installations.

At the present time a somewhat astonishing situation exists with reference to final authority in interpreting disputed provisions or rules of the Code. Influential members of the Electrical Committee take the stand that once the Code for a given year is published and issued to the public there is no recognizable constituted authority, individual or collective, which may legally interpret the Code; that is, render a decision stating exactly how a rule must be understood to apply in given circumstances. The thought here is that once the Code is published, courts only may decide the exact meaning of a rule as written.

Naturally there is a wide disagreement with this viewpoint. A majority of those who have worked on the Code during the years of its development believe that in case of dispute (for instance, between inspector and contractor) a decision or interpretation should promptly be forthcoming from Code headquarters, based upon the chairman's understanding, or the respective Subcommittee's understanding of the meaning of the rule questioned.

From a professional and business standpoint this latter view seems sensible. Recourse to court action would still be open to any person or persons not satisfied with the interpretation of the Code authority.

Some Leaders of the A. I. E. E.

Louis Duncan, the tenth president of the Institute, was born in Washington, D. C., on March 25, 1861. After receiving elementary education, Mr. Duncan was a student for a year at East Tennessee University, and was then appointed to the United States Naval Academy, from which he was graduated in the year 1880.

Following a two-years' cruise on the Pacific he passed the examination for the grade of ensign, being at the top of his class. He was then detailed to Johns Hopkins University, Baltimore, Maryland, to assist in the important work of determining the absolute unit of electrical resistance. For this work he received from the University in 1885, the Ph. D. degree.

In the year 1886 Dr. Duncan resigned from the navy to take the chair of Electricity at Johns Hopkins

University, where he remained until 1899. He was president of the A. I. E. E. throughout the years 1895-6-7. While at Johns Hopkins he served as consulting engineer in the construction of electric railroads in the Baltimore district and in Washington, D. C. For the Baltimore and Ohio Railroad, he engineered the work of providing electric locomotives for hauling trains through the Baltimore tunnel.

In the year 1899 he became chief engineer for the Third Avenue Railway, New York City. In 1902 he was called to Massachusetts Institute of Technology, where he developed the electrical engineering course, remaining as its head until 1904.

Subsequently, he organized the firm of Sprague, Duncan and Hutchinson, and became consulting engineer for the New York Transit Commission on the first subway construction. He served also as chief engineer of the Keystone Telephone Company, Philadelphia, Pennsylvania, and of the independent telephone systems at Baltimore and Pittsburgh.

Dr. Duncan was chairman of the Board of Judges at the Philadelphia Electrical Exhibition in 1885, and a member of the Board at the Atlantic Exposition and the World's Columbian Exposition at Chicago in 1892, and chairman of the electric railroad section of the St. Louis Exposition in 1904.

At the beginning of the Spanish-American War, Dr. Duncan, then a lieutenant-commander in the Maryland Naval Reserve, was appointed major of the first regiment of volunteer engineers. He was a Fellow of the A. I. E. E. and a member of various other scientific and engineering societies. He died on February 13, 1916.

Real Aid at Last for the Teachers

"The subject of light has no practical value in life and consequently is of no interest to the students," said the principal of one of our leading high schools. You smile and I smile, yet the educator who made that remark is only typical of thousands in this country and elsewhere. Too many think of light as a purely theoretical subject and in so doing fail to see its immense practical value. We think of it as a transverse wave motion in the ether propagated at a velocity of 186,000 miles a second, but have failed to understand that light is the most useful of all natural phenomena.

There are but few of us who do not realize the *importance* of modern artificial illumination and yet so few of us are able to *differentiate* between proper and improper illumination. This fact may be due, in part, to the general character of our high school physics courses. The difficulty has been that the high school physics texts in use today have, in a large measure, failed to modernize. They treat the subject of light in a more or less theoretical manner which does not have the popular appeal to the student that a more practical treatment would have; for in general, a student is interested in the mathematical development of a subject, only insofar as its concepts and applications appear in his everyday life.

In view of this fact, the Illuminating Engineering Society has sensed the need for presenting the subjects of Light and Illumination to high school students in a more practical manner; the result has been the appearance of the booklet, "Chapters on Light," recommended for inclusion in high school texts.

In this booklet the mathematical theory of light is not stressed to any great extent, but rather, the effects of light on vision and the importance of light from a practical standpoint are emphasized. A short history of illuminants and a concise discussion of various fundamental units and simplified illumination calculations which supplement the more theoretical considerations usually found in physics texts are included in the "Chapters." In brief, the fundamental principles of light control are treated in a manner which enables the student to differentiate between proper and improper illumination and to adapt light correctly to his daily needs.

This booklet should be a welcome aid to our high school physics instructors. For it does, indeed, inject into this age-old study an interest provoking treatment which allows the student, through his daily experiences, to meet the more theoretical side at least half way.—*Light,* November, 1924.

Awards for Radio Invention

The Institute of Radio Engineers has two awards which are made annually in recognition of meritorious achievement in radio development.

One of these is a large gold medal, awarded by the Institute, which, so far, has been awarded to E. H. Armstrong, E. F. W. Alexanderson, G. Marconi, R. A. Fessenden, Lee De Forest, John Stone Stone and M. I. Pupin.

The other award is that known as the Liebmann Memorial Prize, consisting of the sum of five hundred dollars in cash. This prize has been given to the following: R. A. Weagant, L. F. Fuller, R. A. Heising, C. S. Franklin and H. H. Beverage. For the year 1924, this prize has just been awarded to Mr. John R. Carson, of the American Telephone and Telegraph Company, New York.

These awards are made by the Board of Direction of the Institute. This year the members of the Board are: J. H. Morecroft, J. H. Dellinger, J. V. L. Hogan, Donald McNicol, Lloyd Espenschied, A. H. Grebe, W. F. Hubley, A. N. Goldsmith, Melville Eastham, A. E. Reoch, Edward Bennett, L. A. Hazeltine and H. W. Nichols.

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in generator kilowatts output, giving a fairly accurate check on total losses by a totally different method. At each reading, oscillograms were taken and some of the representative curves are included in this report.

Transformer iron losses were accurately measured on

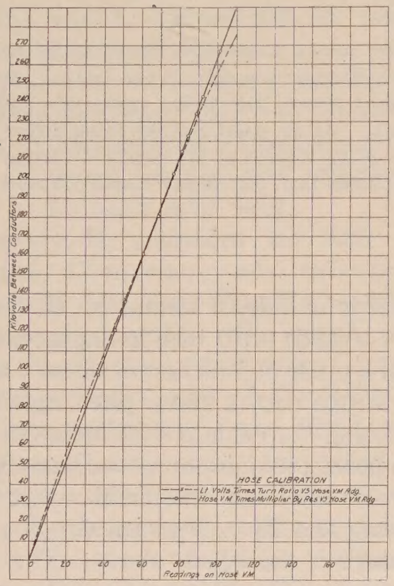

Fig. 13

the transformers in place, and copper losses were calculated and checked against factory measured values.

The I^2R due to charging current in the line was calculated by the method proposed by Jakobsen appearing

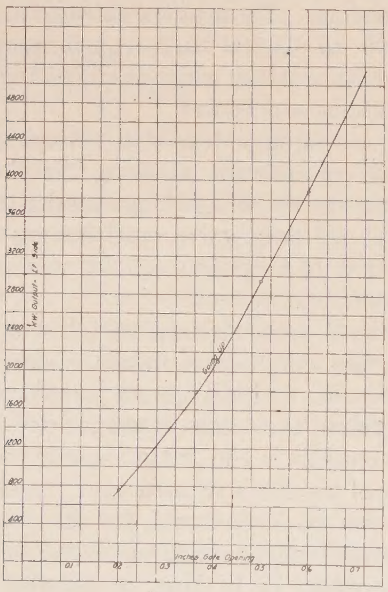

Fig. 14—Calibration of No. 2 Waterwheel Kw. Read on 11 Kv. at 1 Power Factor

in the A. I. E. E. Proceedings. This was checked against the method used by Lewis in the A. I. E. E. Journal of June 1921 and was finally determined by graphically integrating for five-mile intervals.

Using the low-tension readings as a standard, the several loss curves were plotted, using values corrected for instrument and instrument transformers and having the transformer losses subtracted.

These values having the $I^2 R$ of the line subtracted

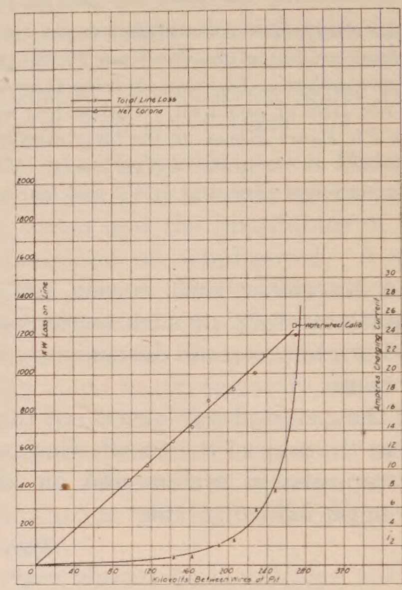

Fig. 21—Corona Loss and Charging Current from Pit No. 1 to Round Mt. Corrected for Transformer Loss—27.5 Miles of Aluminum Horizontal 17—Foot Spacing

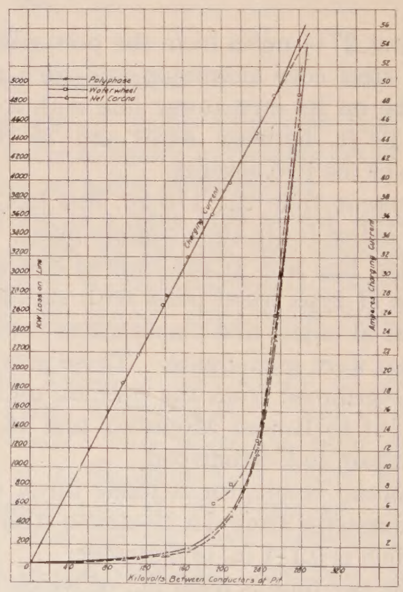

Fig. 22—Corona Loss and Charging Current from Pit No. 1 to Cottonwood

Corrected for Meters and Transformer Losses 27.5 Miles of Aluminum 17 ft. Horiz. Spacing. 32.5 Miles of Copper. 16 ft. Horiz. Spacing

were next plotted and finally the values per wire per mile were plotted. As originally taken, the values for the 15-ft. vertical spacing were obtained by subtraction of two tests and correcting for voltage rise, inas-

much as these values were lower than those of the 19-ft. horizontal spacing. A test was made at Vaca-Dixon Substation charging back 59 miles to Williams. The agreement between these two curves, 29 and 31, is

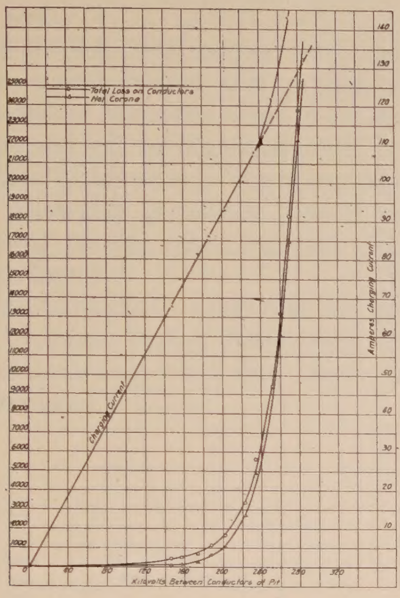

FIG. 23—CORONA LOSS AND CHARGING CURRENT FROM PIT No. 1 TO WILLIAMS

Corrected for Meters and Transformer Losses.
27.5 Mi. of Aluminum 17 ft. Horiz. Spacing
32.5 Mi. of Copper 16 ft. Horiz. Spacing
83 Mi. of Copper 15 ft. Vert. Spacing

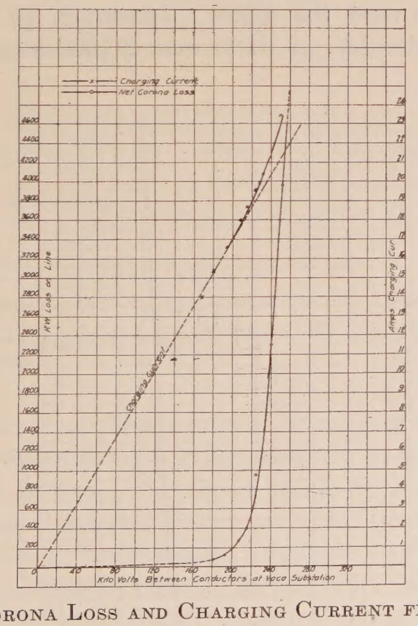

FIG. 24—CORONA LOSS AND CHARGING CURRENT FROM VACA—DIXON TO WILLIAMS

Corrected for Meters and Transformer Losses 5.9 Miles Copper 15 ft. Vertical Spacing

very good and as all the values at Pit are checked against the waterwheel output, it is felt that reliable results are obtained.

TEST RESULTS

There are included four sets of data:—

1—A test from Pit to Round Mountain from which Curves 21 and 27 are plotted.

2—A test from Pit to Cottonwood from which Curves 22, 25 and 28 are plotted.

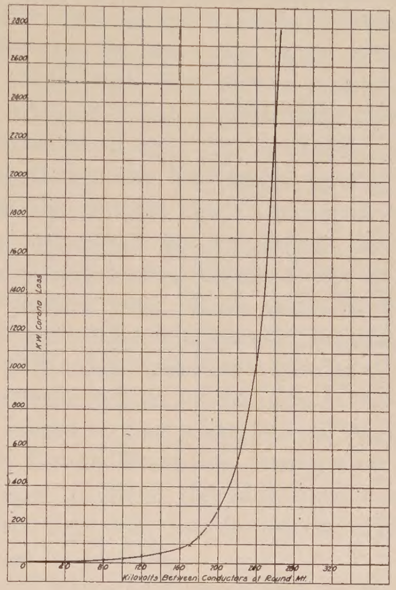

FIG. 25—CORONA LOSS—NET. ROUND MT. TO COTTONWOOD

From Difference of Two Tests. 32.5 Mi. of Copper 16 ft. Horiz. Spacing. Corrected from Voltage Rise from Pit to Round Mt.

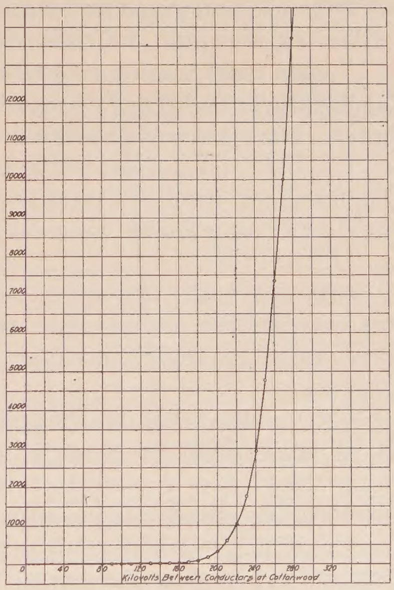

FIG. 26—CORONA LOSS—NET. COTTONWOOD TO WILLIAMS

From Difference of Two Tests. 83 Miles of Copper, 15 ft. Vertical Spacing. Corrected for Voltage Rise from Pit to Cottonwood.

3—A test from Pit to Williams from which Curves 23, 26 and 29 are plotted.

4—A test from Vaca-Dixon to Williams from which Curves 24 and 30 are plotted.

There is included a curve of the hose calibration, the water-wheel calibration, the transformer losses, one comparing the high-tension readings, and finally, curves

plotted on semi-log paper showing the general law of the loss measured.

Calibration Low-Tension Readings

The instruments were calibrated at the approximate power factor used before the test and after completion

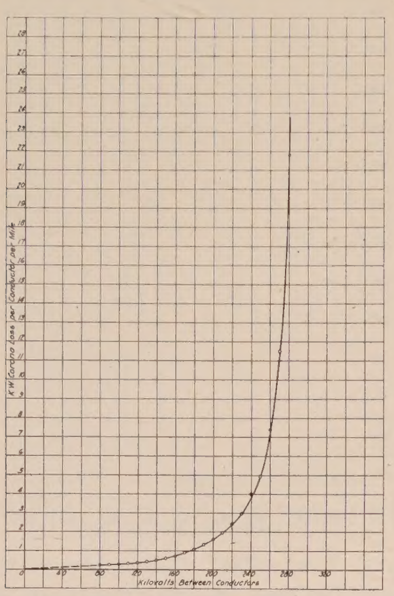

Fig. 27—Corona Loss on Steel Core

52684 Cu. Cm. Aluminum 1.06 in. Diameter. 17 ft. Hor. Spacing at 10 Deg. Cent. and 27 in. Bar Wires to Ground 50 ft. at Towers. Wires to Ground 30 Min. in Span.

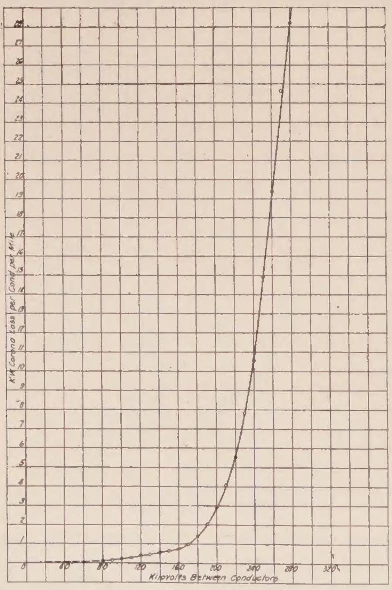

Fig. 28—Corona Loss on Rope Strand

500,000 Cm. Copper. 17 ft. Hor. Spacing at 11 Deg. Cent. and 27 in. Bar. Wires to Ground 50 ft. at Tower. Wires to Ground 30 ft. Min. in Span.

rechecked at the test power factor and load readings. The instrument transformers were calibrated for ratio and phase angle and the values for correction taken from curves. These corrections individually were never more than 1.2 per cent when applied to the low-tension readings, and when combined, were less than the individual corrections as they were in opposite directions.

These corrections were applied, although it is believed

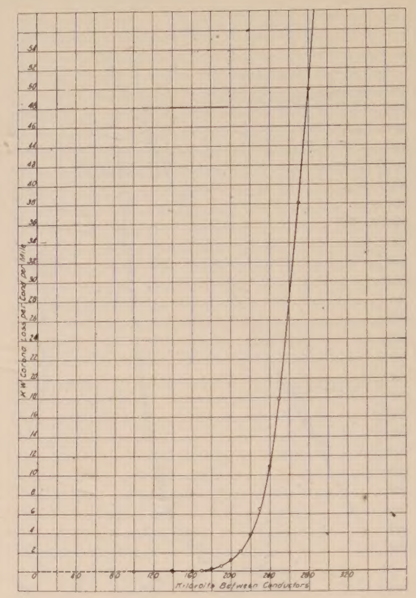

Fig. 29—Corona Loss on Rope Strand

500,000 Cm. Copper. 15 ft. Vert. Spacing at 11 Deg. Cent. and 28 In. bar. Bottom Wire to Ground 55 ft. at Tower. Bottom Wire to Ground 30 ft. Min. in Span. Derived Curve.

they were very close to the accuracy with which it was possible to read the meter. Inasmuch as the losses were considerable, at times over 20,000 kilowatts, the

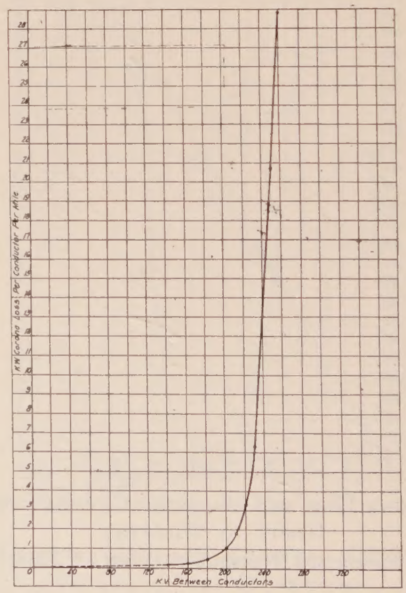

Fig. 30—Corona Loss on Rope Strand 500,000 cm. Copper

readings were for the most part well up on the meter scale.

Calibration High Tension. The voltmeter on the high tension was calibrated first by using the *low tension*

voltage at the turn ratio with the transformer alone excited from the low tension; and second, by measuring the hose resistance by two independent methods and using this resistance in the usual multiplier formula correcting by several approximations for the shunted part of the hose.

The high-tension wattmeters were calibrated for approximate power factors but on test showed very consistent curious reversals which were studied somewhat further and will be discussed later.

Water Wheel Calibration. The water-wheel was calibrated in kilowatts generator output against gate opening, using special small current transformers at unity power factor.

While somewhat crude, these readings are manifestly unaffected by power factor, phase angle, etc., and give considerable assurance when they check the more precise measurements.

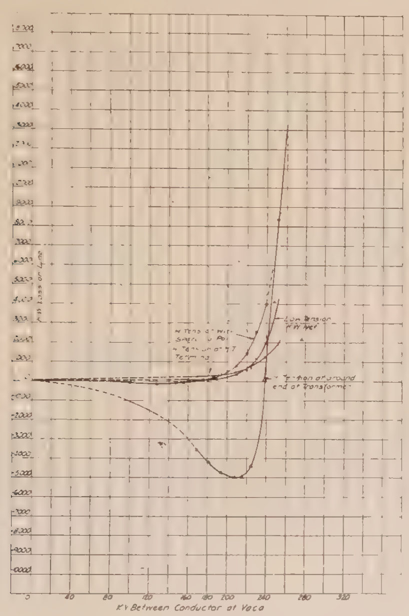

FIG. 31—CORONA LOSS CURVES FROM VACA-DIXON TO WILLIAMS

Cor. for Meters and Transformer Losses. 59 Miles Copper. 15 ft. Vertical Spacing.

Barometer and Temperature. Barometer and temperature readings were taken and are included in the data. No attempt has been made to reduce these values to sea level and 25 deg. cent. for the reason that the only correction formulas available contain several unknown factors not directly measurable, and inasmuch as the results depart from the general law of which these factors are a part, it was thought best to give the data as secured.

Observed Corona. Under normal running conditions photographs of the line with a very high grade commercial lens and a quartz lens loaned by Mr. Peek, were made and are included.

Considerable effort was exerted in trying to discover if there were any corona or other emanations or disturbing influences present around the insulators that could be photographed; all gave negative results.

It should be borne in mind that most of the exposures are for considerable time and therefore show more corona than would be visually observed under the same conditions; and that a film of the character used is much more sensitive than the eye to corona discharge.

It is noticeable, as has been noted before, (Lewis, A. I. E. E., June 1921) that corona is most profuse on the middle conductor and in proximity to the ground; also it can be noted that the conductor next to the parallel circuit on the horizontal spacing has more corona than the outside one. Inasmuch as the conductors are transposed on the circuits under test, the individual conductor losses check, as was demonstrated repeatedly during test. It is difficult, however, to include any such effect in a general formula, taking account only of the mean geometric spacing of conductors.

Only a representative set of data is given for each test. For instance, four complete curves were taken from Pit to Round Mountain during two consecutive days, in order to check the high-tension wattmeters, giving points that fall exactly on the same curve as nearly as can be plotted.

The several instruments were read by more than one person to avoid any personal errors and every precaution used to see that no faulty connections or equipment were used.

In all there were used:

1—Calibrated turbine gate opening.

2—Low-tension kw., amperes and volts.

3—High-tension voltage from hose.

4—High-tension kw. from the ground end of the high-tension transformer winding, and voltage from the ground end of the hose.

5—High-tension kw. from the line end of the transformer high-tension winding and the high-tension end of the hose.

6—High-tension kw. using the ground end of the transformer high-tension winding and potential from the spare transformer and an 11-kv. potential transformer.

7—Oscillograms at each reading.

A study of each of these leads to the following conclusions:

1—The turbine gate opening calibrated in kw. generator output at unity power factor is, of course, approximate, due to the difficulty of reading accurately, but being affected by neither power factor nor phase angle, it gives an added assurance when it checks the more accurate methods.

2—The low-tension kw. were used as a standard and every precaution used to secure accurate data.

The curves given are based on these readings and the several other methods considered as checks against them.

3—High-tension voltage was measured directly on a voltmeter and the hose described above.

This hose was left in service several days to determine

whether there would be any deterioration or change due to change in water resistance.

For the same conditions no change could be detected, though for conditions which caused considerable leading current to flow through the transformers the voltage rise above the turn ratio was greater than the usual calculations indicate. (See Lewis, A. I. E. E., 1921).

4—In the original scheme it was decided to use the current in the ground side of the transformer high tension and potential from the ground end of the hose, giving the loss on one conductor.

In practise, it was found that the wattmeter reversed part way up the curve and gave apparent losses much higher than the known generator load.

It was finally decided that this was due to phase angle, but no practical field method of calibrating it could be found.

An attempt was made to shield the hose by enclosing

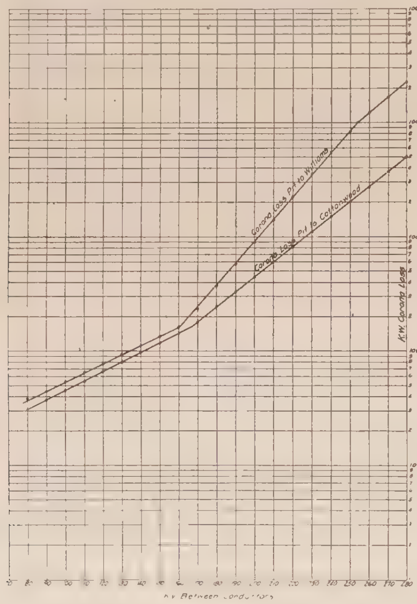

FIG. 32

it in a larger hose, running water up the inside and down between the two sizes of hose and using the inner hose on the wattmeter with no practical change in results.

5—The wattmeter was shielded and its current coil put directly in the line using the top part of the hose for potential.

This gave high results at low voltages and low results at high voltages.

6—During the time that the tests were carried on at Pit, an attempt was made to measure the loss in one conductor from Vaca to Williams using the ground of the transformer high tension and the spare transformer, together with an 11-kv. potential transformer to supply voltage.

This gave similar results to the original hose combination, being negative at low voltage and high at high voltages, the negative values being much less as shown in curve 31.

Some two weeks later this was checked in addition to low-tension readings and for the same physical conditions even though read by a different person on another meter. The curve, so far as could be read, was exactly the same and showed an appreciable negative loop at low voltages.

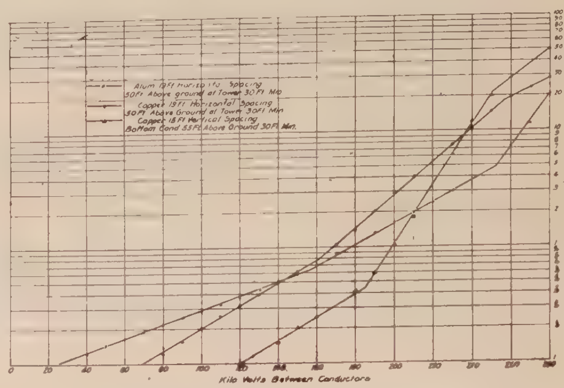

FIG. 33—CORONA LOSS IN KW. PER WIRE PER MILE

The low-tension readings checked very closely the losses determined at Pit for the same configuration.

These several combinations of high-tension readings are plotted in curve together with the low tension for the same configuration.

By applying a correction for phase angle, these check the low-tension readings and while the phase angle could be calculated approximately, no direct measurement could be taken. They are, therefore, included only as a matter of interest and an indication of the difficulties of direct high-tension measurements.

The method of correcting for instruments, transformers and $I^2 R$ losses has been described and mention has been made of the voltage correction.

From Pit to Round Mountain the voltage rise was of very little importance being in the order of one kv.

With more lines added, as from Pit to Williams, the rise is appreciable and since it was desired to determine

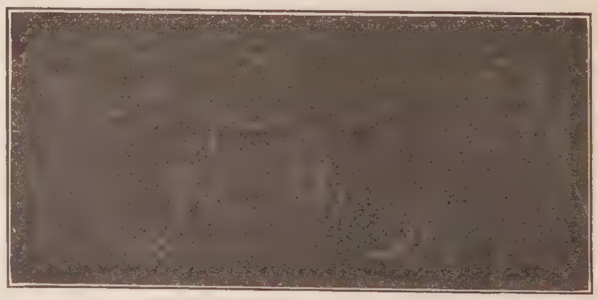

FIG. 34—PIT NO. 1. WAVE FORM NO. 2 GENERATOR. NORMAL SPEED, NORMAL VOLTS DISCONNECTED

the loss from Round Mountain to Cottonwood and Cottonwood to Williams, the voltage rise was calculated using the values of line constants determined by the test in the convergent series formulas.

It was discovered that the losses as taken followed an exponential law and plotted a straight line on semi-

logarithmic paper. This allowed us to correct the losses in small enough sections that the voltage rise over that section was inappreciable.

This voltage rise correction was not thought to be essential but was carried out for the loss from Round Mountain to Cottonwood and from Cottonwood to Williams.

This last was checked by an entirely separate test

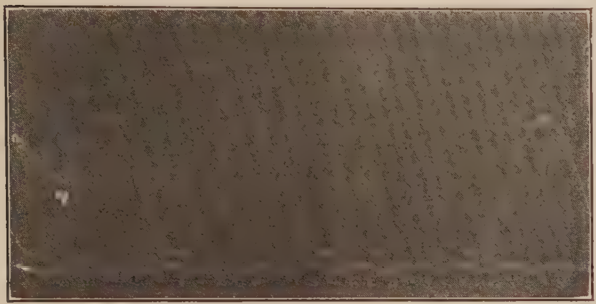

Fig. 36—Corona Loss Tests. Pit-Vaca 220-Kv. Line. Corona Loss Pit to Williams

1—Ground Current Less than 10 Amperes
2—Line Amperes 108 eff.
3—Line Voltage to Ground 135,400 eff.

from Vaca to Williams taken at Vaca and plotted for voltage at Vaca.

This checks almost exactly the corrected curve from Cottonwood to Williams, indicating that the method used was correct.

The final results are given in loss per mile per wire on a line in which the rise in voltage was very small and so can be used to build up the losses on a similar line of

Fig. 37—Corona Loss Tests. Pit-Vaca 200 Kv. Line. Corona Loss Pit to Williams

1—Ground Current 10 Amperes eff.
2—Line Current 121 Amperes eff.
3—Line Voltage to Ground 144,600 eff.

any length, provided the voltage along it is known and short sections used; it also allows us to determine what the losses under load conditions would be on a line with a lower voltage at the receiving rather than at the sending end.

From the final results it will be noticed that the portion of the line having a comparatively low horizontal spacing has a higher loss for low voltages (even with the conductors farther apart) than the higher vertical spacing.

On the higher voltages the closer spacing has the higher loss. This indicates that the distance to ground has considerable effect on the loss and may at times overshadow the distance between conductors.

As the voltage is increased, a point is finally reached where the slope of the curve changes so that the increase in loss per kv. increase in voltage is less than on the lower part of the curve.

At this point the current wave begins to be distorted and a 180-cycle ground current flows, which at the higher voltages, reaches values of one-third of the total charging current.

This is clearly shown in Figs. 36, 37 and 38 wherein the oscillograph remained unchanged, only the line voltage being raised. This has been discussed in previous papers, though the fact that the actual corona loss does not increase as fast with increase in voltage as at the lower voltages does not seem to have been noted. (Peek, A. I. E. E., July 1921), (Lewis A. I. E. E., 1921).

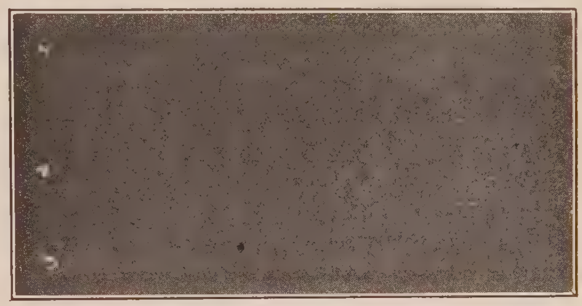

Fig. 38—Corona Loss Tests. Pit-Vaca 220-Kv. Line Corona Loss pit to Williams

1—Ground Current 45 Amperes eff.
2—Line Current 143 Amperes eff.
3—Line Voltage to Ground 156,200 eff.

For the aluminum wire this point could not be reached because of the larger conductor and comparatively short line.

There is, however, a break in the aluminum loss line at about 155 kv. between conductors. This is below the visual corona and it has been suggested that it is connected in some way with the insulating film on the conductor and the ionization around it.

The curves secured seem to divide the corona loss into three phases as regards line voltage.

1—Losses below the point where the corona is visual, called by Professor Ryan dark brushes and discharging free ions.

2—The visual corona in which the losses are considerable and the increase in kw. loss per kv. rise in voltage is greater than in Case 1.

There visual brushes are formed and ionization by collision is the important loss medium.

3—At a point sufficiently high in voltage a considerable third harmonic flows, deforming the current wave (see oscillograms Figs. 36, 37 and 38) and decreasing the slope of the curve, *i. e.*, having less loss increase in kw. per kv. increase than 2.

The loss has the nature of a gas electrical hysteresis with half arc characteristics and at this point the charging current deviates from a straight line indicating that the dimensions of the conductor have in effect increased (see Curve Fig. 23) as suggested by Peek, A. I. E. E., July 1921.

So far there has not been sufficient data accumulated to make any attempt to formulate a law or fit to the existing laws in order to determine what the loss would be for conditions other than those under which the data were taken.

There is no regularity in either their position or direction and they seem to flit back and forth along the conductor remaining only a fraction of a second in one place.

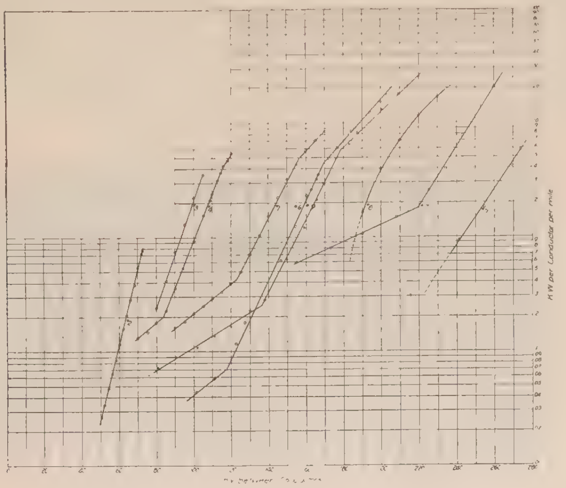

FIG. 40

No. 1. Lewis Curve No. 18 Page 1109 A. I. E. E. Data divided by 3×101.5 to get Kw. per Conductor per Mile

No. 2 Jakobsen Curve "C" page 103 A. I. E. E. 1818 Data divided by 3×68.4 to get Kw. per Conductor per Mile—

No. 3. Faccioli page 341 A. I. E. E. 1911 Data divided by 3×153.5 to get Kw. per Conductor per Mile

No. 4. Faccioli Curve "C" page 342 A. I. E. E. 1911 Data divided by 3×63.5 to get Kw. per Conductor per Mile

No. 5. Wood page 723 A. I. E. E. 1922. Kv. multiplied by 1.73 to get Kv. between conductors

No. 6. Peek, High Voltage Engineering page 248 Test 146 Reduced to Miles

No. 7. Clark & Ryan. Pit-Vaca Conductor 18 Spacing, Bar 30.01 In. Temp. 67.5 Deg. Fahr.

No. 8. Peek. Pit-Vaca Conductor Dec. 1921, 16 ft. 10 in. Spacing 25 Deg. Cent. 76 Cm. Bar. $M_0 = 68$

No. 9. Peek High Voltage Engineering Page 122. Reduced to Miles

It was noticed that no rain drops collected on the 220-kv. conductors as they did on the 110 kv. of the same size conductor in the same tower.

In the higher elevations the same effect is noticed with the snow, it being harder, of course, to see just what happens to the brushes.

Roughly, from station meters, the corona loss seems to be approximately doubled, dropping back to normal again as soon as the storm ceases.

A great many engineers have stated that it is advisable to run below the visual corona point. This statement is open to question and the final solution is economic rather than technical.

The $I^2 R$ loss on the line under discussion at full load is 8500 kw. approximately. As the voltage is lowered to decrease corona the $I^2 R$ increases and conversely when the voltage is raised to decrease $I^2 R$ corona increases. There is, therefore, a certain point most efficient which in territory subject to storms would be lower than that for the same conductor in a more advantageous climate.

At present there seems to be no way of determining what the corona loss on a proposed line will be at the voltage present practise gives it to operate, and this is the particular region in which power company engineers are interested.

The losses at voltages below visual corona are considerable and if known might in certain cases vary the size of conductor used 100 per cent (see Jakobsen, A. I. E. E., 1918).

On the line tested, the losses are greater for a line close to the ground even though it has a greater spacing. This is not accounted for in present formulas.

In lines where several constructions of line are alternates this will affect the design and therefore the cost, and is important.

The curves as finally plotted, together with such tests as have been published from time to time by the Institute, give a series of straight lines on semi-logarithmic paper throughout their entire range corresponding to the several physical changes noted.

These curves are plotted from the original data as given in the several references, the changes necessary to reduce them to kilowatt loss per conductor per mile being also noted.

In tests such as those of Lewis the condition nearest approximating the 220-kv. test configuration and connections was plotted.

These curves were plotted to compare with the form of curve observed on the test and all of the actual transmission line tests obtainable seem to show this exponential form.

From the original test made in 1921 on a 300-ft. section of the copper conductor, the irregularity factor was given as 0.68. After reviewing the tests as made on the line, this has been changed to 0.72. Both of these values are used in the quadratic formula under test conditions of temperature and barometer and plotted together with the values of the test in Curve 20.

The observed loss would indicate for the test conditions approximately 22,000,000 kw-hr. per year, the value of 0.68 and the quadratic law 43,000,000 kw-hr. per year and the value of 0.72 approximately 24,000,000 kw-hr. per year.

These represent losses in the order of $100,000 per year and bear out the statement that it is desirable to know the loss under operating conditions. A more thorough understanding of the physical causes and mechanics of corona loss is gradually being reached. This is hopeful and if, from lines existing and now being built, it is possible to secure the data for determining these losses, it will be more and more worthwhile as longer lines and higher voltages come to be used.

Electric Power Application
in Pacific Northwest Fir Mills

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THE timber resources of the Great West are estimated at about 1450 billion feet of saw timber or about one-half of the total stand in the United States. Of the remaining stands, the South has about one-fourth and the remainder of the United States one-fourth.

The important timbers found on the Pacific Coast suitable for lumber manufacturing are fir, hemlock, redwood, spruce, larch, yellow fir, cedar and white pine.

Due to the gradual depletion of the Southern forests, the center of production, which until very recently was in the South, has shifted to the Pacific Northwest. Many of the larger lumber manufacturers of the South have either moved their plants to the Northwest or have purchased tracts of timber and are making plans for new manufacturing plants. The output of the Pacific Coast is already exceeding the south.

The immense size of the timber on the Pacific Coast demands extra heavy duty machinery for all operations from logging to final finishing plant. The experience of past practise in other sections of the country was of little value in determining the correct machinery for this size of timber. It was therefore necessary to do considerable experimenting until well defined practise was settled upon.

The use of electric power in the mills of the Pacific Northwest, although of recent date, has been a gradual development alongside with the machinery that it was necessary to drive. As with the milling machinery, so with the electrical machinery, the experience of others sections of the country was of little value.

The application of electric drives to sawmill machinery in the Pacific Northwest dates back to less than fifteen years, when a few applications were made in driving certain sections of the mill by a single motor belted to a line shaft. This motor was usually installed to replace a worn-out steam engine or else due to necessary increase in production, the boiler plant was found of insufficient capacity to take care of this increase. The mill operator then found he could buy electric power from the local central station without delaying production. The great advantage of the motor over the steam engine in driving sawmill machinery was soon realized by the lumber manufacturer and soon after complete electrification of sawmills was begun.

In the early mill electrification, the main milling machines were each driven by individual motors but all transfer chains, live rolls, conveyors, etc., were grouped together and each group driven by a motor. This necessitated a certain amount of transmission machinery such as shafting, belts, frictions, etc. At the present time the practise is, in addition to milling machinery, to drive each section of rolls, chains, conveyors, etc., with individual motors. The elimination of this great amount of transmission machinery from the sawmill has been a big factor in the final decision of the sawmill industry in deciding on electrification. At the present time by utilizing air instead of steam on log deck machinery, steam may be entirely eliminated from the sawmill proper and complete electrification obtained.

The three general branches of lumber operation which may either be carried on by one organization or by three or more separate organizations, are logging, sawmilling, planing mill or finishing plants.

LOGGING

Logging consists of felling the tree, cutting it into length suitable for transportation, "yarding" or gathering the logs to railroad spur or river bank and loading these logs on cars to be hauled to the sawmill. Electricity is being applied at the present time by six large operators on the coast for yarding and loading. The successful operation of these units has caused many other operators in considering changing over their steam logging equipment to electric.

SAWMILLING

Sawmill operation is generally spoken of as that part of the operation from the time the train of log cars arrives at the mill site until it is converted into suitable lumber for the finishing plant or planing mill. After the logs arrive at the mill site, they are unloaded from the cars into the log pond. The logs are then sorted and cut to desired length by the drag saw in the log pond, after which they are transferred to the log deck inside of the mill, either by log haul or log hoist. From the log deck they are forced on the carriage by steam or air niggers. In case the shape of the log is irregular, an overhead power-driven canting gear is used to help place the log on the carriage. After the log is placed on the carriage, the latter is run back and forth past the head saw. Each time it finishes a cut, the power-driven set works is set to move the log forward to the size of cut desired. The timbers, cants or slabs obtained in the operation fall on the main live rolls. The timbers generally travel the entire length of the mill on live rolls, and at the end are transferred to either a timber planer to be "sized" to correct dimension or are trans-

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ferred for shipment. The cants are transferred by power-driven chains from the main live rolls to live rolls in front of the edger, where the cants are cut by the gang of saws in the edger to desired widths. These boards are then transferred to chains in front of the automatic gang saw trimmer where they are trimmed, and cut into standard length. From here the boards go on to the sorting tables where boards are sorted for grade lengths, thickness and width.

In some mills, in order to increase the capacity and at the same time obtain vertical grained boards, the cants, as they leave the head saw, are transferred to a sash gang. Two or more of these cants are stacked in front of the gang by an electrically operated overhead transfer and are then fed through the gang and turned into one or two inch boards. These boards then go to the trimmer for trimming and from there to the sorting table.

The slabs as they come from the head saw are also transferred to the edger where they are cut into desired widths and then transferred to the slasher where they are cut in suitable lengths for either shipment of cord wood, stock of lath mill, or fuel hog.

In the larger mills, the head saw, instead of cutting the logs up into boards, breaks it up into thick cants. When these finally arrive on the sorting table, after going through the different operations mentioned above, they are then transferred to a portion of the mill called the remanufacturing plant. This plant consists of one or more band resaws, vertical or horizontal, pony edgers, trimmers and slashers, the finished lumber finally returning to the sorting table. The remanufacturing plant can really be considered as a "miniature sawmill," as all the operations performed are similar to that in the main sawmill. By the addition of the remanufacturing plant, the output of the plant which is limited by the capacity of the main head saw, can be increased considerably.

After leaving the sorting table, the lumber is either shipped out "green," or if necessary to meet correct thickness and width, it is put through an automatic sizer or transferred to a power driven stacker where the boards are stacked on edge on cars and put in a dry kiln for removing moisture in the lumber.

After leaving the dry kiln, the power-driven machine unstacks the cars and the lumber is transferred to a sorting table. After sorting, the lumber is ready for the planing mill or for shipment.

Planing Mill or Finishing Plants

The lumber from the sorting table is brought into the planing mill in bundles by electric cranes or carriers. These bundles of lumber are placed on rolls in front of surfacers, matchers or moulders. The finished product from the latter machines passes over chains and are then trimmed by either single cutoffs or by pony gang saw trimmers. Other machinery in planing mills are small resaws and rip saws. For handling of shavings from planing mill machinery, a power-operated blow pipe system is installed. This blows the shavings through pipes into the power house fuel bin.

Type of Electrical Equipment

Practically every drive in a sawmill, with few exceptions, may be driven with a constant speed motor. As a result it lends itself very happily to the use of alternating curent, three-phase 60-cycle current. At present there are four different voltages used in sawmills, namely—220, 440, 550 and 2200, although 440 and 2200 volt predominate. The latest electrically-driven mills are standardizing on 2200 volt for 40 h. p. and above and 440 volt on motors below 40-h. p. capacity. When it is necessary to use direct current, a motor-generator set is usually installed.

The types of motor to be used in sawmills, although few in number, are very important. Due to the abuse a motor gets in a sawmill, on account of dust, dirt and, in some instances, excessive dampness, it is very important that the most reliable type be used. The squirrel-cage induction motor, due to its simplicity and sturdiness is used wherever possible. By the use of a squirrel-cage type motor with high-resistance rotor, a large number of drives, such as rolls, transfer chains and conveyers, requiring high starting torque, and of short duration, may be driven without the use of friction. In a few cases of roll and transfer chains where very frequent starting and reversing of motor is desired, it is desirable to use a wound rotor induction motor with permanent external resistance, arranged for special service. Some of the milling machinery, such as band headsaws, gang saws, band resaws and heavy duty slab conveyor require high starting torque and that this torque be maintained for a considerable time, due to the flywheel or heavy load to be started and accelerated to full speed. In this case a wound rotor with heavy duty starting resistor and operated by drum controller is used.

The control equipment for the motor drives in a sawmill has been given a great deal of consideration, due to the peculiar and continuous severe condition of operation. At the present time nearly every mill of any size is equipping its motors with magnetic control. A great deal of labor in lumber mills is unskilled. By using magnetic control, starting is made considerably easier, the operator is kept away from the control and the maintenance of the equipment is reduced materially.

Head Saws

There are two types of head saws used in sawmills, circular and band. The older mills have circular saws but most of the mills that have been built of late are equipped with band head saws.

The circular head rig, except small pony rigs, consists of two saws mounted one above and slightly ahead of the other. Small pony rigs consisting of one circular saw are also used in mills where logs of very small diameter are cut up or where cants coming from a main

rig are cut up. The double circular head rig, due to the small starting torque required, is usually driven by a squirrel cage type of motor. This motor is direct connected to the arbor of the lower saw and the top saw is belted to the arbor of the bottom saw. (Fig. 1 shows a 500-h. p. motor driving a circular head rig.)

Fig. 1—Double Circular Head Rig Driven by a 500-H. P. Induction Motor

The band head saw is almost totally taking the place of the circular saws in the newer mills and is replacing circular head saws in older mills. Due to the heavy starting torque required to accelerate the heavy bottom wheel of the band mill, a wound-rotor motor should be used. This motor should have three bearings. (See

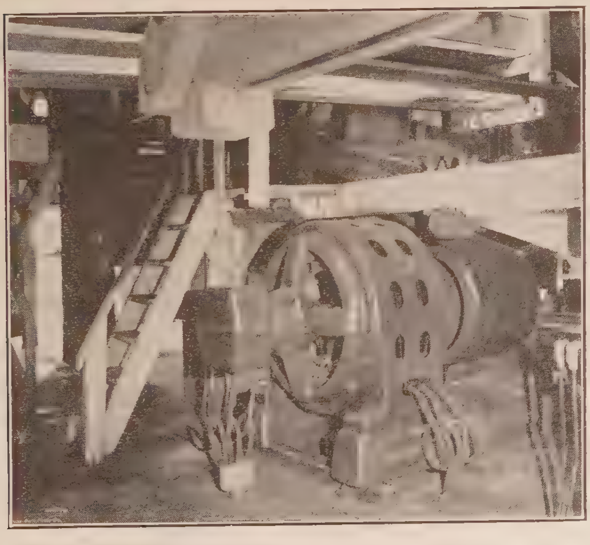

Fig. 2—300-H. P. 3-Bearing Induction Motor Equipped with Enclosed Collector Rings Driving 11-Ft. Band Mill

Fig. 2). On account of the location of this motor in the mill, a large accummulation of fine dust on the controller rings usually results. It is therefore recommended that the motor be so designed that its collector rings should be enclosed in metal dust proof protection case. The control for the band mill motor should be automatic. The cost of such control is more than hand control; yet, when the additional cost of hand control wiring is considered, since in automatic control the main wires do not have to be carried to the main saw floor from which the starting and stopping operation is controlled, it will be found to be very little more than hand control. The control for this motor (See Figs.

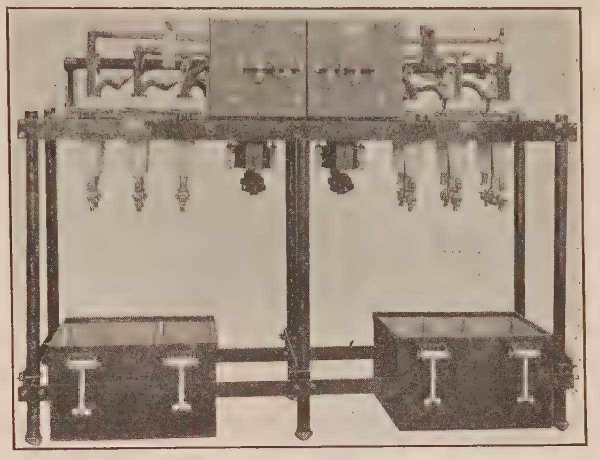

Fig. 3—Primary Magnetic Reversing Control for Band Mill Motor

3 and 4) should have full magnetic primary and secondary control for both starting and plugging. The control should be provided with adjustable current-

Fig. 4—Secondary Magnetic Control for Band Mill Motor

limiting equipment to maintain accelerating torque when starting, and to maintain retarding torque at approximately 160 per cent of full-load torque when plugging. The control equipment should also be provided with inverse time limit overload and under-voltage protection. The plugging feature in this control is very important in the larger mills, as it saves

considerable time whenever it is necessary to stop the band mill to change saws. By means of this plugging feature, the band mill is brought to rest in 30 to 40 sec. The sawyer who operates the band mill and motor, con-

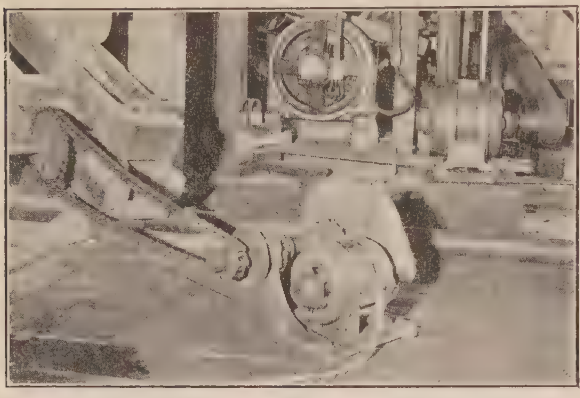

Fig. 5—Sawdust Conveyer Driven by Back-Geared Motor

trols the latter through a three-point push button marked "Start" "Reverse" "Stop." If he wishes to stop the motor quickly, he presses the reverse button and holds it down until the motor comes to rest, then releases the button before the motor starts up in the reverse position.

The size of motor for band mills varies considerably in different size saw mills. In mills where short logs

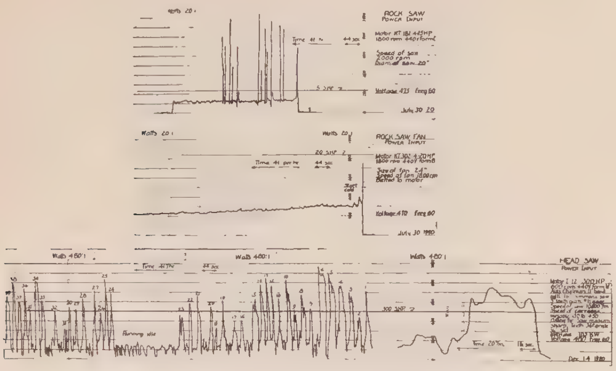

Fig. 6—Tests of Motors Driving Rock Saw, Rock Saw aFn and Band Mill

are used, a smaller motor may be installed than in mills employing longer logs. The sawyer generally feeds the log to the saw at a rate that will obtain maximum production and at the same time not impose too much strain on the saw. The motor at times is called upon to withstand peaks of twice its normal rating during the period the saw is in the cut.

Live Rolls and Transfer Chains

The application of individual motors to each section of rolls and transfer chains has resulted in a greater total saving in the operation of a sawmill than any other equipment installed. It has eliminated a great many frictions which are extremely expensive to keep up and require frequent replacement. Also a larger amount of other transmission equipment which was a source of trouble, such as shafting, pulleys, belts, etc., were eliminated.

The individual drive consists of a motor with a gear reducer and roller chain driving from the back shaft of

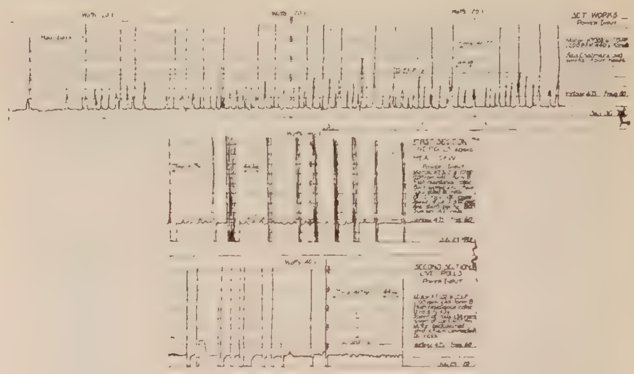

Fig. 7—Tests of Motors Driving Sections of Live Rolls and Set Works

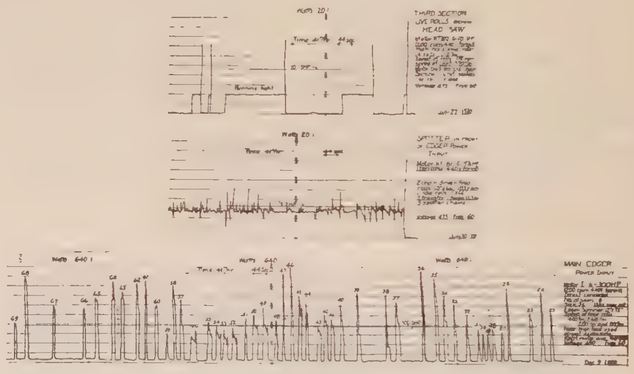

Fig. 8—Tests of Motors Driving Sections of Live Rolls, Edger Spotter Chains and Main Edger

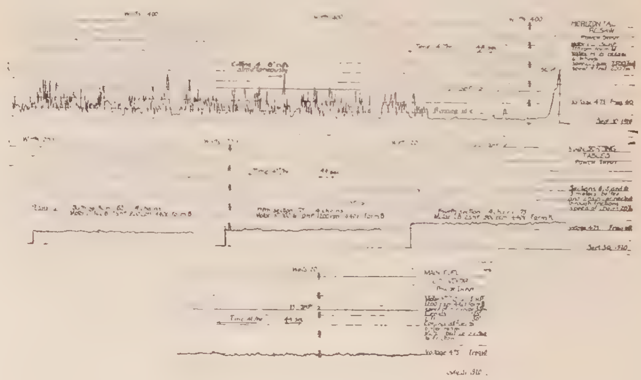

Fig. 9—Tests of Motors Driving Sections of Sorting Table, Horizontal Resaw and Main Fuel Conveyor

the gear reducer direct to the live roll or transfer chain shaft. These motors may be either standard squirrel-cage, wound-rotor with starting duty resistor, squirrel-cage with high-resistance rotor or wound-rotor type with special permanent external resistance.

The following are recommendations as to type of

TABLE I
MAIN SAWMILL

Motor Driving	H. P.	Type of Motor	Type of Control	Method of Drive
Log pond cutoff saw	20-25	Slip ring	Drum controller with start. Duty resistor	Belted to drag saw reciprocating mechanism
Canting gear	10-15	Varying speed slip ring intermittent service	Reversing drum controller with crane type resistor	Geared
Log haul	40-100	Slip ring varying speed	Magnetic speed regulator operated by master controller	Geared
Log Hoist	50-75	Varying speed slip ring intermittent service solenoid brake	Reversing drum controller with crane type resistor	Geared
Rock saw	15	Squirrel cage	Magnetic switch with 2-point push button	Belted
Rock saw fan	20	Squirrel cage	Automatic compensator with 2-pt. push button	Direct connected
Set works	7½-10	Squirrel cage	Magnetic switch with 2-pt. push button	Geared or belted
7 ft. band head saw	100-150	Slip ring 3-bearing	Automatic control for starting and plugging with 3-point push button	Belted
8 ft. "	150-200	"	"	"
9 ft. "	250-300	"	"	"
10 ft. "	300	"	"	"
11 ft. "	300-400	"	"	"
9 ft. Double cut band head saw	250-300	"		"
60 in. sing. circular head saw	200	Squirrel cage	Automatic compensator with 2-pt. push button	Direct connected
Double circular head saw	300-500	"	"	Motor direct-connected to bottom saw. Top saw belted from bottom saw arbor
8 in.-edger	150	"	Automatic compensator with 2-pt. push button	Direct connected
10 in.-edger	200	"	"	"
12 in. and 14 in.-edger	250-400	"	"	"
Edger feed rolls	10-20	2- or 4-speed constant h. p. squirrel cage	Pole changing reversing cont. with magnetic line switch	Back geared drive from back shaft to feed roll shaft
4-band edger	Four 100 h. p.	Slip ring	Automatic starter with 2-pt. push button	Each band belted to one-100 h. p. motor
Shifter for band edger	10	Slip ring with external permanent resistance	Magnetic reversing switch with master control switch	Motor connected to screw drive on band
Band edger feed rolls	10	Two speed constant h. p.	Pole changing reversing controller with magnetic line switch	Back geared—chain drive from back shaft to feed roll shaft
Automatic gang saw trimmer	50-75	Squirrel cage	Automatic compensator with 2-pt. push button	Direct connected to drive shaft
Slab slasher	75-100	"	"	Direct connected to saw arbor
Timber trim saws	25-30	"		Belted to saw pulley
Main live rolls	7½-10	Squirrel cage high resistance rotor	Magnetic reversing switch with 5-pt. push button or master switch	Back geared—chain drive
Rolls front of edger	5	Squirrel cage	Magnetic switch with 2-pt. push button	"
Rolls back of edger	7½-10	"	Magnetic reversing switch with 3-pt. push button	"
Transfer chains from one set of rolls to another	5-7½	Squirrel cage high resistance rotor	"	"
Transfer chains table behind head rig for transferring cants to pony rig	20	"	"	"
Kick of chains in live rolls	5	Slip ring with external permanent resistance	Magnetic reversing with 3-pt. push button	Back geared—chain driven
Floor table chains to slasher	15-20	Slip ring with starting duty resistor	"	"
Trimmer table chains	10	Squirrel cage high res. rotor	Magnetic rev. switch with foot control switch	"
Rolls behind trimmer	7½	Squirrel cage	Magnetic switch with 2-pt. push button	"
Sawdust conveyor under head saw	5	"	"	Back geared—chain driven
Trash conveyors under carriage	7½-10	Squirrel cage high res. rotor	"	"
Cross conveyor and lengthwise conveyor	20-30	Slip ring with start. Duty resis.	Automatic control with 2-pt. push button	"
Conveyor to fuel bin	15-20	Squirrel cage	Automatic compensator with 2-pt. push button	"
Conveyor under trimmer	15	Slip ring with start. Duty resis.	Automatic control with 2-pt. push button	"
Conveyor to burner	20-40	"	"	"
36 in. hog	60	Squirrel cage	Automatic comp. with 2-pt. push button	Direct connected
42 in. hog	75	"	"	"
48 in. hog	100	Slip ring with start. Duty resis.	Automatic control with 2-pt. push button	"
60 in. hog	150	"	"	"
32 in. sash gang	75	"	"	Belted
44 in. "	150	"		"
48 in. "	150-200	"		"
54 in. "	200	"		"
60 in. "	250	"		

MAIN SAWMILL—*Continued*

Motor Driving	H. P.	Type of Motor	Type of Control	Method of Drive
Loading rolls front of gang	7½	Squirrel cage	Magnetic reversing switch with 5-pt. push button	Back geared—chain driven
Jump saw front of gang	30	"	Automatic compensator with 2-pt. push button	Belted
Rolls behind gang	7½	"	Magnetic switch with 2-pt. push button	Back geared—chain driven
5-band gang	500	Slip ring	Automatic control with 3-pt. push button	Each band belted from jack shaft
6-band gang	600	"	"	"
Band gang feed	25	D-c. adjustable speed	Reversing hand controller with armature and field resistance	Back geared chain driven
3-saw wood saw	30	Squirrel cage	Automatic compensator with 2-pt. push button	Direct-connected to saw arbor
4-ft. wood chains	5	"	Magnetic switch with 2-pt. push button	Back geared—chain driven
Lath bolter	40-75	"	Automatic compensator with 2-pt. push button	Direct connected
Lath machine	30-50	"	"	"
Lath trimmer	5-7½	"	Magnetic switch with 2-pt. push button	"
First section of sorting table and sections that must be started with accumulation of lumber	10	Slip ring with external permanent resistance	Magnetic switch with jog point push button	Back geared—chain driven
All other sections of sorter table	10	Squirrel cage with high resistance rotor	"	"
6-ft. vertical resaw	75	Slip ring with start. Duty resistor	Automatic control with 2-pt. push button	Belted
7-ft. vertical resaw	100	"	"	"
7-ft. horizontal resaw	150-200	Slip ring—3 bearing with starting duty resistor	"	"
Resaw feed rolls	6	Four speed squirrel cage constant h. p.	Pole changing controller and primary line magnetic switch	Back geared—chain driven
Transfer chains to resaw	7½	Slip ring with external permanent resistance	Magnetic switch foot controlled	"
Poney edger	30	Squirrel cage	Automatic compensator with 2-pt. push button	Direct connected
Pony trimmer	30	"	"	"
Ready sizer 8 in. by 20 in.	50	"	"	"
Blower for ready sizer	50	"	"	"
Stacker	10	"	Magnetic switch with 2-pt. push button	Belted
Unstacker	10	"	"	"
Incline chain to stacker	5	"	"	Back geared—chain driven
Unstacker sorting chains	10	"	"	"
Timber sizer	75	"	Automatic compensator with 2-pt. push button	Direct connected
Blower for timber sizer	50	"	"	"
PLANING MILL				
8 in. by 9 in. moulder 60 ft./min.	20	Squirrel cage	Automatic comp. with 2-pt. push button	Direct connected
12 in. by 6 in. "	40-50	"	"	"
6 in. by 15 in. matcher 175 ft./min.	50	"	"	"
High speed matcher or surfacer:				
Main				
Drive	75	"	"	"
Side heads	25	"	"	"
Profile	25	"	"	"
High speed matcher—individual motors:				
Vertical spindle	Two-20	"	Automatic magnetic switch with 2-pt. push button station	"
Horizontal spindle	Two-25	"	"	"
Feed	25-15	Two speed squirrel cage	Pole changing controller with magnetic switch	Chain drive
Rip saw or profile	25	Squirrel cage	Automatic magnetic switch with 2-pt. push button	Direct connected
High speed 6 by 12 moulder—individual motor drive				
Horizontal spindle	Two-20	"	"	"
Vertical "	One-10 One-7½	"	"	"
Feed	One-7½	"	"	Chain drive
High speed 6 by 9 moulder—Individual motors:				
Horizontal spindle	Two-10	"	Magnetic switches with 2-pt. push button station	Direct connected
Vertical "	Two- 5	"	"	"
Feed	One- 5	"	"	Chain drive
Resaw	30-40	"	Automatic compensator with 2-pt. push button	Belted or direct connected
Rip saw	20	"	"	Belted
Single trim saw	3-5	"	Magnetic switch	"
Gang trim saws	20	"	"	Direct connected
Hog	75	"	Automatic compensator	"

SHINGLE MILL

Motor Driving	H. P.	Type of Motor	Type of Control	Method of Drive
Cut-off and log haul	75	Squirrel cage	Hand compensator	Belted
Splitter saw	50	"	"	"
Shingle machine	20-25	"	Automatic compensator with 2-pt. push button	Direct connected
Clipper saw	3	"	Magnetic switch with 2-pt. push button	"
Splint conveyor	7½	"	"	Back geared—chain drive
Burner conveyor	10	"	"	"
Block "	5	"	"	"
Spalt conveyor	5	"	"	"

motors to be used for individual sections of live rolls or transfer chains:

Squirrel-Cage Type, Non-reversing.

Rolls front of edger
Rolls back of sash gang
Rolls behind trimmer.
All sections of sorting table except first section and sections that do not usually have accummulation of lumber.

Squirrel-Cage Type, Reversing.

Rolls back of Edger.

Squirrel-Cage, High-Resistance Rotor, Reversing.

Main Live Rolls
Transfer Chains from one set of rolls to another
Transfer Chains behind head rig for transferring cants to pony rig.

Slip Ring type with special permanent external resistance, Reversing.

Kick-off chains in live rolls
Trimmer table chains

Slip-Ring Type with special permanent external resistance, Non-reversing

Transfer to resaws.
First section of sorting table and sections that must be started with accumulation of lumber.
Floor table slasher chains.

Due to the frequent starting, stopping, jogging and reversing of their drives, the motors are thrown directly on the line by means of magnetic contactors. These contactors are controlled either by a master switch or push button station.

The accompanying table gives power requirements and type of electrical equipment as applying to fir mills on the Coast. For pine mills, due to the small size of logs and also different methods of manufacturing, the power requirements are considerably less—approximately about one-half that shown in the column "horse power" of this table.

Power Factor Correction

The power factor of the load in a sawmill equipped with individual motor drive is very low, sometimes reaching 65 per cent lagging. This may be corrected by installing synchronous motors on the fan in the planing mill and also for driving the air compressor used for furnishing air to different equipment around the sawmill.

Some of the mills have installed a synchronous condenser of sufficient kv-a. capacity for correcting the power factor of the entire system.

Energy Consumption

Figs. 6 to 9 inclusive show instantaneous power input of various motors in a representative Pacific Coast fir mill.

The total energy consumed by a mill is a variable quantity due to various factors which enter into sawmill loads, peculiar to the individual operations.

A fir mill cutting mostly rough timbers for cargo shipment will probably require about 40 kw. hrs. per 1000 ft., while one cutting for rail shipment necessitating considerable additional work in the remanufacturing plant and planing mill, requires about 60 to 70 kw. hrs. per 1000 ft. The average kw-demands of these plants are as a rule equal to the total connected horse power load divided by two.

For pine mills, the average kw. demand and also the kw-hr. consumption per 1000 ft. is about 60 per cent that of a fir mill.

A NOTABLE ACHIEVEMENT IN ELECTRICAL ADVERTISING

The advances in the field of electrical advertising have by no means lagged behind developments in other fields. This fact has been revealed with more emphasis than ever before with the appearance within recent months of a new electric sign in New York City of enormous proportions. This sign is nearly a full city block in length and is as high as a five story house. Over its vast framework, 21 miles of wire distribute 267 kilowatts of energy to its 19,000 lamps.

When the 29 flashers start this display into operation, there comes a crimson glow which rises, spreads and brightens—beautiful color combinations appear until, with a rush and a sparkle, there blazes out the full radiance of the Northern Lights.

A plump jolly faced Eskimo then appears, all bundled up in his white furs. He sits on an artic sled and, as he gaily speeds along, streaks of sparkling snow shoot backward from the runners.

The Eskimo faces the crowds and grins merrily, then he snaps his whip (which by the way is 66 feet long) and his team composed of three more little Eskimos, all smaller editions of himself, jerk their heads to the front, and off they go, their little legs flying over the snow at a great rate.

The driver carries on his sled a mammoth bottle of ginger ale, as tall as most three-story buildings. Quickly, he cracks his whip again, and the words "Cliquot Club" flash against the sky in light blue and white. * * *—*Signs of the Times*, August, 1924.

Practises in Telephone Transmission
Maintenance Work

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IT is the purpose of this paper to present a general picture of the practical applications of methods of measuring transmission efficiency in the Bell System which have been developed by study and experience under plant operating conditions. The rapid growth of the telephone industry has made it necessary that these methods be such as to allow them to be applied on a larger scale in a systematic and economical manner.

Transmission maintenance can be broadly defined as that maintenance work which is directed primarily towards insuring that the talking efficiencies of the telephone circuits are those for which the circuits are designed. There are, of course, many elements which affect the talking efficiency and various d-c. and a-c. tests are available for checking the electrical characteristics to insure that they are being maintained in accordance with the proper standards. In the final analysis, however, an overall test of the transmission efficiency of a circuit in the condition it is used in service will show at once whether it is giving the loss, or, in the case of amplifier circuits, the gain which it should give. Transmission tests, therefore, offer a means whereby many of the electrical characteristics can be quickly and accurately checked.

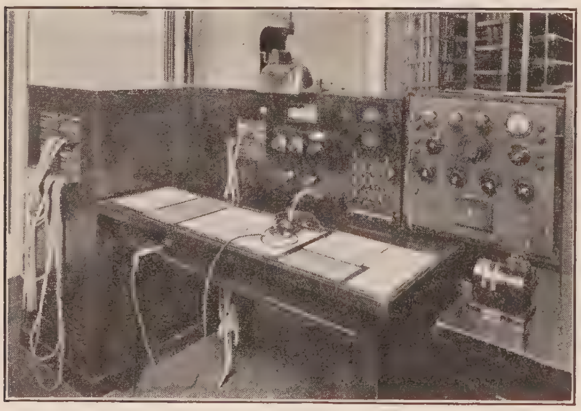

FIG. 1—ILLUSTRATION OF 4-A TRANSMISSION MEASURING SET AND 4-B OSCILLATOR INSTALLED IN A TOLL TEST ROOM

The testing apparatus used in this work and the different parts of the telephone plant concerned have been described in previous Institute papers[1]. At the last annual convention in Chicago a paper was also presented discussing the transmission unit which has recently been adopted in the Bell System and which is used in transmission maintenance work to express losses and gains in telephone transmission. The present paper describes how the testing apparatus which has been developed is applied in a practical way in the telephone plant. The main body of the paper relates particularly to tests of volume efficiency and the applications of methods for maintaining this efficiency in accordance with the proper standards. Certain other testing methods equally important in transmission maintenance work are also extensively used and some of the more important of these are briefly discussed in Appendix A of the complete paper.

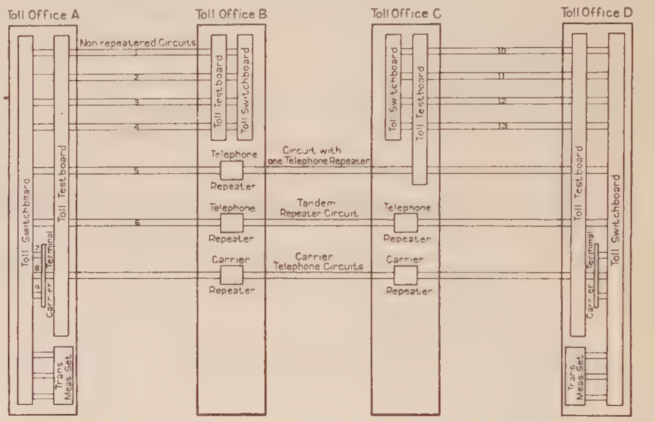

FIG. 2—SCHEMATIC DIAGRAM OF TYPICAL TOLL CIRCUIT LAYOUT TO ILLUSTRATE GENERAL METHOD OF TESTING NON-REPEATERED, REPEATERED AND CARRIER CIRCUITS

The routine procedures in testing toll circuits using transmission testing apparatus differ considerably from those followed in the local or exchange area plant and the toll and local practises have therefore been considered separately.

TRANSMISSION TESTS ON TOLL CIRCUITS

With regard to overall toll circuit transmission testing, Fig. 1 shows a typical installation of a transmission measuirng set with its associated oscillator designed particularly for this work. The set is provided with trunks to both the toll test board and toll switchboard and also with call circuits to toll operators' positions for use in ordering up circuits for test. The electrical measuring circuit is designed so that tests may be made on two toll circuits looped at the distant end or straight-away on one toll circuit, the distant terminal of which terminates in an office equipped also with a transmission measuring set of the same general type.

Toll circuits as operated today can be divided into three general classes as far as the transmission mainte-

Abridgment of paper presented at the Pacific Coast Convention of the A. I. E. E., Pasadena, Cal., October 13-17. Complete copies to members on request.

1. See Bibliography.

nance requirements are concerned, namely, non-repeatered circuits, circuits equipped with telephone repeaters, and circuits equipped for carrier operation. Fig. 2 shows a typical layout involving these three classes and indicates schematically the general arrangement for overall testing. A logical procedure for the arrangement shown is for offices *A* and *D* to test the non-repeatered circuits 1 to 4 and 10 to 13 by having them looped two at a time at the distant terminal offices *B* and *C*. For the circuits 5 to 9 extending between offices *A* and *D* equipped with telephone repeaters or carrier, straight-way measurements can be made to the best advantage in each direction with the sets, making it possible to test all of the longer and more important toll routes in the System. At the smaller offices where fixed transmission measuring sets are not warranted, the toll testing work is done by the use of portable sets in connection with other maintenance work.

In the Bell System there are at the present time more than 20,000 toll circuits in service. The circuits making up this system are of various types and construction depending on the service requirements and length and also upon certain other factors determined by engineering and economical design considerations. In order that the people responsible for maintaining the trans-

Fig. 3—Map Showing Locations in Bell System of Permanent Transmission Measuring Sets

mission efficiency of these circuits be fully familiar with the layout, a toll circuit record card system has been developed. Fig. 4 shows a sample of the card now generally used. This card provides space for recording the detailed makeup of a toll circuit, including the equipment associated with it. Such a record is valuable not only in giving the maintenance forces a picture of the circuits which they are testing, but it also furnishes a means for establishing the transmission standards to which they should work.

two transmission measuring sets provided. Overall tests on the carrier circuits do not differ in any way from the tests on repeatered or non-repeatered circuits, each carrier channel being tested as a separate circuit through the switchboard. The measuring current is modulated and demodulated in the same manner as voice currents under regular operating conditions and the measured equivalent, therefore, indicates the overall transmission efficiency. Experience has shown that, due to the more complicated makeup of the repeater and carrier circuits, routine transmission tests on these are required at more frequent intervals than on the non-repeatered circuits.

Fig. 3 shows the locations in the Bell System of the general type of testing apparatus shown in Fig. 1. There are now in operation between 40 and 50 of these

One very important feature in toll transmission is the use of amplifiers in telephone repeater and carrier systems. The various arrangements of amplifiers to provide for telephone repeater and for carrier operation make up integral parts of toll circuits and introduce elements in the circuits which have to be given particu-

lar local attention in maintaining the overall transmission efficiency. The chief items to be observed in both carrier and repeater maintenance are that the gains specified to give a desired overall transmission

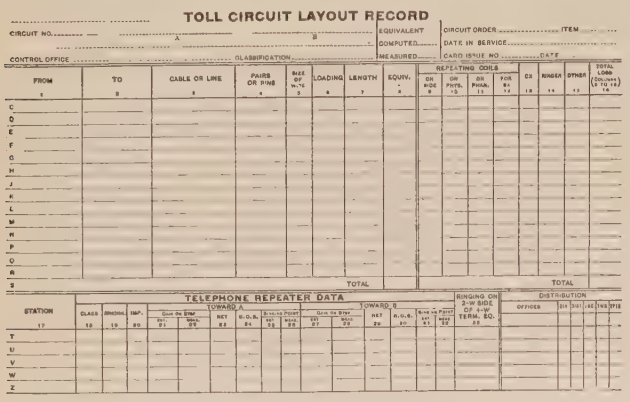

FIG. 4—SAMPLE OF A TOLL CIRCUIT LAYOUT RECORD CARD

equivalent be kept as constant as possible, that these gains remain fairly uniform within the range of frequencies involved and that conditions do not exist which will disturb the overall balance between the circuits and networks sufficiently to cause poor quality of transmission.

Considering telephone repeater maintenance, Fig. 5 shows a schematic diagram of a 22-type repeater and indicates the important tests which are made locally to insure that the apparatus is functioning in a satisfactory manner as a part of a toll circuit. The numbers applied to the different tests listed in the figure show approximately the points in the repeater circuit at which the tests are made, the purposes of the tests being evident from their names.

When carrier operation is applied to toll circuits, an additional transmission system is introduced involving the use of currents of higher frequencies than those in the voice range. From a maintenance standpoint this

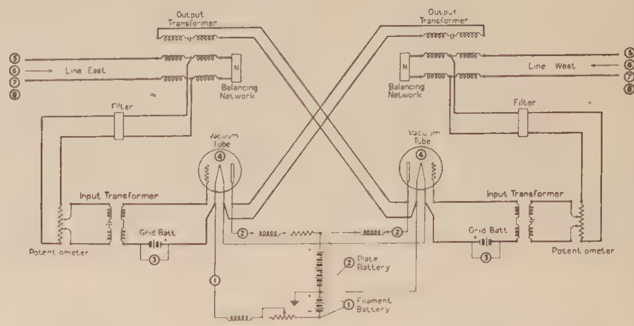

FIG. 5—SCHEMATIC DIAGRAM OF A 22-TYPE TELEPHONE REPEATER SHOWING IMPORTANT LOCAL TRANSMISSIOM MAINTENANCE TESTS

1. Filament Current and Voltage
2. Plate Current and Voltage.
3. Grid Voltage and Poling.
4. Vacuum Tube Activity Tests.
5. Gain Tests (Working Potentiometer Steps).
6. 21-Circuit Balance Tests.
7. Potentiometer Step-Gain Tests.
8. Gain Frequency Tests.

means that certain additional testing methods must be employed which will insure the proper generation and transmission of the carrier currents, and that the modulation and demodulation of the voice frequency currents are accomplished without distortion or excess loss in overall transmission. To give a general picture of the more important features involved in the transmission maintenance of carrier systems, Fig. 6 shows a schematic diagram of a carrier layout having one carrier repeater. It will be noted that three series of tests are required, one for the carrier repeater, one for the carrier

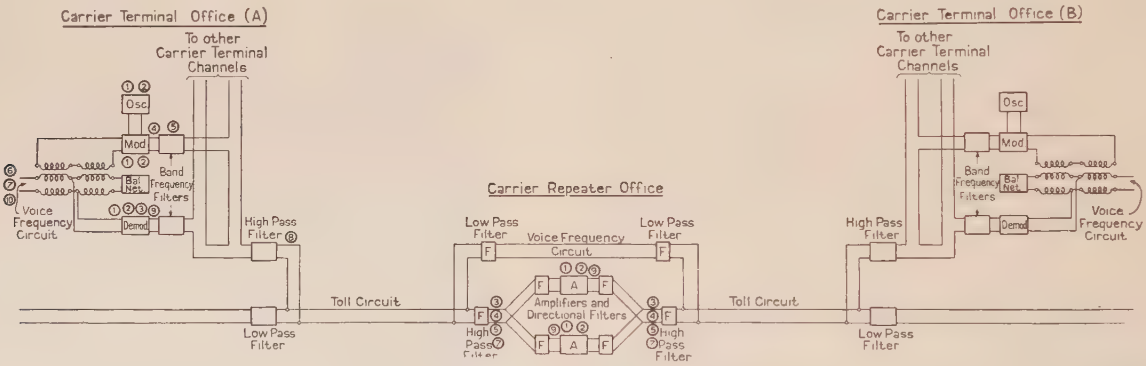

FIG. 6—SCHEMATIC DIAGRAM OF A CARRIER TELEPHONE SYSTEM SHOWING IMPORTANT TRANSMISSION MAINTENANCE TESTS FOR CARRIER REPEATERS, CARRIER TERMINALS AND OVERALL

CARRIER TERMINAL TESTS

1. Filament, Plate and Grid Battery Tests.
2. Vacuum Tube Activity Tests.
3. Channel Rectified Received Current Tests.
4. Modulator Output.
5. Modulator Band Filter Output.
6. Channel Loop Gain Tests.
7. 21 Circuit Balance Tests on Voice Frequency Circuits.

Overall Tests of Complete Carrier System

8. Tests of total Carrier Output Current into Toll Circuit.
9. Tests of Carrier Current at Repeater Outputs and finally Rectified Received Current at Distant Terminal.
10. Overall Transmission Tests.

CARRIER REPEATER TESTS

1. Filament, Plate and Grid Battery Tests.
2. Vacuum Tube Activity Tests.
3. Gain Tests.
4. Potentiometer Step-Gain Tests.
5. Gain-Frequency Tests.
6. Check of Frequency of Test Oscillator (not shown in figure).
7. High Frequency Singing Tests.
9. Output Current on Overall Test of System.

CARRIER TERMINAL TESTS Similar to those listed for Office A.

terminals and one for the system as a whole. The nature of these various tests and the approximate points in the carrier system where they are applied will be evident from the names and numbers shown in the figure. For both telephone repeater and carrier systems, provision is made in the regular testing equipment so that the tests can be very quickly applied both as a routine proposition and also when required for trouble location.

TABLE I

Classification of Circuits in the Exchange Area Plant Important from a Transmission Maintenance Standpoint

MANUAL OFFICES

Local Switchboards	P. B. X. Switchboards	Toll Switchboards	Toll Testboards
Cord circuits	Cord circuits	Cord circuits	Composite set circuits
Operators' circuits	Operators' circuits	Operators' circuits	Composite ringer circuits
Trunk circuits	Trunk circuits	Trunk circuits	Phantom & simplex circuits
Miscl. circuits	Miscl. circuits	Miscl. circuits	Miscl. circuits

Subscribers' loops and sets
Operators' telephone sets

MACHINE SWITCHING OFFICES

Panel	Step by Step
District selectors	Connectors
Incoming selectors	Toll selectors
Trunk circuits	Trunk circuits
Miscl. circuits	Miscl. circuits

Subscribers' loops and sets
Operators' telephone sets for
Special service positions

General classes of exchange area circuits involving equipment other than contacts and wiring which affect telephone transmission.

Fig. 7—Illustration of a 3-A Transmission Measuring Set Being Operated in a Manual Office

Transmission Tests on Exchange Area Circuits

The tests mentioned thus far apply particularly to toll circuits extending between exchange areas and to the amplifier equipment directly associated with these circuits. Considering now the exchange area plant, the transmission conditions are important, not only from the standpoint of insuring good local service, but also to insure good toll service, since the local plant forms the terminals of toll connections. The exchange of local plant offers a somewhat different transmission maintenance problem than the toll plant, particularly with respect to the routine testing procedures which must be followed to insure satisfactory transmission. This will be evident when it is considered that in each city and town a complete telephone system is in operation which involves the use of a large number of circuits of various types. There are also in use three general types of telephone switching equipments—manual, panel machine switching and step-by-step machine switching, and in certain cities combinations of these equipments. The general classes of circuits making up these systems which are important from a transmission maintenance standpoint are listed in Table I.

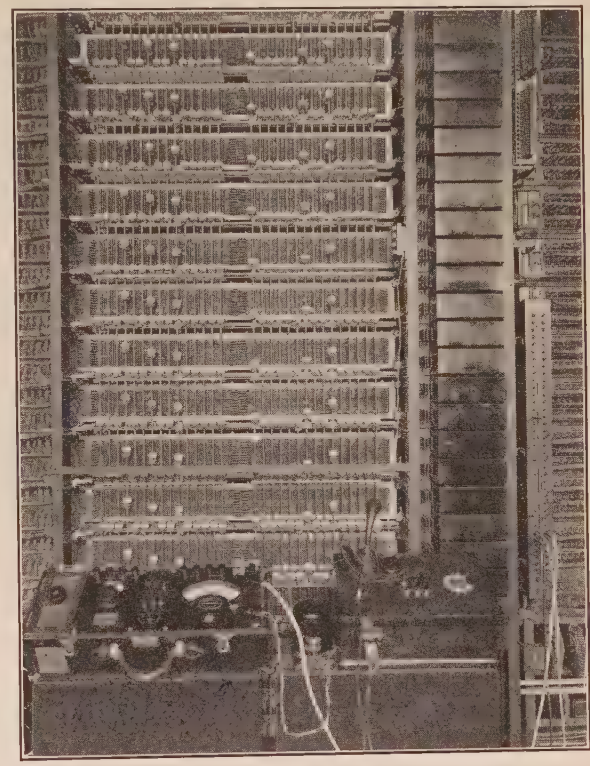

Fig. 8—Illustration of a 3-A Transmission Measuring Set, Set up in a Panel Machine Switching Office for Testing District Selectors

In order to give a general picture of the application of transmission testing to the different classes of circuits shown, a brief discussion of the methods employed in both manual and machine switching systems is given in the complete paper. In either system the loop method of testing proves most satisfactory, that is, one measuring set is used, and where both terminals of a circuit are available as in cord circuits, a loop test through the individual circuit is made. This is illustrated in Fig. 7 which shows a portable transmission measuring set being operated at an *A* switchboard position to test cord circuits.

Considering transmission tests on machine switching circuits, these are similar to those on manual circuits

but involve special methods for picking up the circuits and holding them while the measurements are made. The standard types of transmission measuring sets are used in this work in conjunction with the regular testing equipment provided in the machine switching offices, and the methods which have been developed offer a quick and convenient means for making the tests. Machine switching systems offer an important advantage in transmission testing work, particularly in trunk testing, in that the circuits can be looped automatically by the use of dials or selector test sets, thereby doing away with the necessity for having someone at the distant office complete the loops manually.

Fig. 8 shows a portable transmission measuring set, set up in a panel machine switching office for making tests on district selectors. To illustrate the general method of testing machine switching circuits, Fig. 9 shows two schematic arrangements, the upper diagram being for tests on panel trunks and the lower diagram for tests on step-by-step trunks. The general principles of the methods employed will be evident from these schematic diagrams. Briefly described, two spare terminals are cross-connected at the distant or looping office and all trunks in a group tested, two at a time, from office *A* by automatically looping them through the cross-connected spare terminals at office *B*.

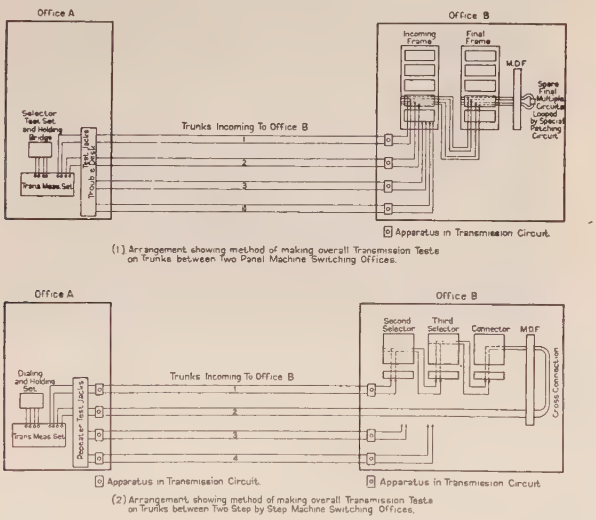

Fig. 9—Schematic Diagrams Showing Methods of Making Transmission Tests on (a) Trunks Between Panel Machine Switching Offices and (b) between Step by Step Machine Switching Offices

The plan being followed in the Bell System for systematically checking the transmission conditions of exchange area circuits is to have all offices tested periodically by men equipped with portable transmission measuring sets who travel from office to office. Fig. 10 shows a typical transmission testing team layout. The team is equipped with an automobile which proves an economical means of transportation between offices and exchange areas and provides a convenient method for carrying the testing equipment.

With a testing plan of this kind, large areas can be covered by a small traveling force with a small amount of testing equipment. One of these teams, for example, tests all of the transmission circuits exclusive of subscribers' lines in a 10,000-line central office, either manual or machine switching, in a period of from two to four weeks, any trouble found being cleared as the testing work is done.

Results Accomplished

In discussing the results accomplished by transmission maintenance work, the paper considers in some

Fig. 10—Illustration of a Typical Transmission Testing Team Layout

detail the kinds of trouble which adversely affect transmission and which can be detected and eliminated by routine testing methods. The remedial measures which are applied to eliminate any troubles found depend largely, of course, on the nature of these troubles and their location in the plant.

In the above discussion some of the more important features involved in the problem of maintaining a high grade of transmission efficiency in a large telephone plant as it exists today have been pointed out. Experience with the testing methods described has shown that these methods can be applied in a comprehensive and economical manner with very satisfactory results. This type of maintenance work, however, is only well started and consideration is continually being given to new testing methods and their applications in order that further improvements in service may be effected and increased economies in testing taken advantage of.

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Harmonics Due to Slot Openings

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Review of the Subject.—*This paper represents a brief graphical-analytical exposition, followed by a mathematical development of the harmonics due to slot openings not included in this abridgement. These were proved to be even and odd multiples of the number of slots plus and minus one. The modifications upon the torque speed curves of these harmonics have been discussed. A simple Fourier analysis underlies the whole phenomena.*

* * * * *

THE object of this paper is to give in Part I a graphical-analytical demonstration and in Part II a mathematical demonstration of the harmonics caused by slot openings. The description applies particularly to the field form of a rotating field motor such as the induction motor.

Part I.

Tooth harmonics affect the performance of the motor in several ways, the more important, from a practical point of view, being the low-speed counter-torques causing cusps in the speed-torque characteristic and noise.

The depth of the cusp in the speed-torque characteristic depends upon the magnitude of the low-speed counter-torque, which in turn depends upon the intensity of the harmonic field. It is therefore, both interesting and important that the order and magnitude of the harmonics be determined for the practical case. The solid line Fig. 1 shows the speed-torque curve of an induction motor with the effect

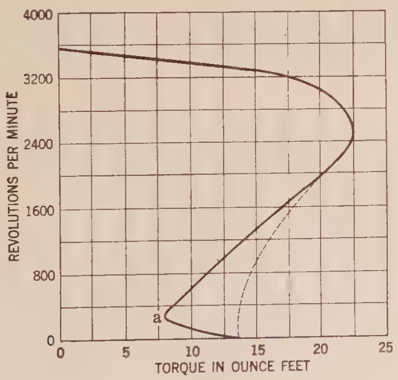

FIG. 1

of tooth harmonics shown at *a*. The dotted portion of the curve indicates the shape of the speed-torque curve if tooth harmonics were eliminated.

For the purpose of simplification, the rotating field of an induction motor only was considered and to further simplify the work involved in this anaylsis, five slots per pair of poles were assumed and the dimensions of the tooth were assumed to be in proportion to the dimensions of the teeth of a punching having the usual number of teeth. By using five teeth per pair of poles instead of the usual number in a standard motor, a large amount of unnecessary labor

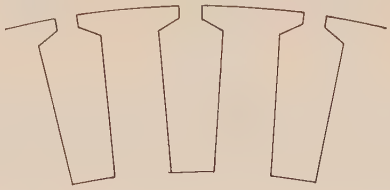

FIG. 2

was avoided. By making the shape of the teeth of the five-tooth rotor in proportion to the usual number of teeth in a standard motor, the equivalent of practical conditions was obtained. These assumptions produced a tooth of proportions shown in Fig. 2.

The air gap was of the usual size for the smaller sizes of induction motors and in this case 0.015 in, on one side.

After obtaining the normal size of tooth and slot opening of a five slot per pair of poles element, and assuming the air gap to be 0.015 in., the tooth and air gap were laid to a scale ten times normal size in order to draw in the tooth fringing as shown in Fig. 3.

The center line of the tooth was taken as the starting point and the distance from center line of slot to center line of tooth was divided into 36 equal parts and the flux paths measured at these points along the fringing lines shown in Fig. 3. Since the field strength is proportional to the reciprocals of the lengths of the paths, the reciprocals of the measured lengths were calculated and the data in the first two columns of Table I was prepared for plotting the reciprocal curve shown in Fig. 4. Since the maximum field strength is a direct function of the largest reciprocal, Column 3 of Table I was prepared on the basis of putting the per cent maximum flux equal to the largest reciprocal and other values in direct proportion. Fig. 5 was then plotted from data in Columns 1 and 3 in Table I. This curve, Fig. 5 has the same shape as Fig. 4, but the ordinates are given in per cent maximum flux instead of reciprocals which is more convenient. Curves, Figs.

*The authors are indebted to Mr. R. E. Hellmund for valuable suggestions.

Abridgment of paper presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924.

4 and 5 illustrate the effect of the slot opening on a uniform field.

Since the field in the air gap of an induction motor is assumed to be sinusoidal, the curve shown in Fig. 5

TABLE I

Position in Degrees	Length from Drawing	Reciprocals of Lengths
0-29.7	0.15	6.67
30	0.3	3.33
31	0.75	1.33
32	1.2	0.833
33	1.65	0.606
34	2 1	0.476
35	2.5	0.40
36	2.97	0.337
37	2.5	0.40
38	2.1	0.476
39	1.65	0.606
40	1.2	0.833
41	0.75	1.33
42	0.3	3.33
42.3-72	0.15	6.67

was multiplied by the sine curve and the instantaneous field obtained as shown in Fig. 6. Two points, one at *a* and the other at *b* are calculated below to illustrate

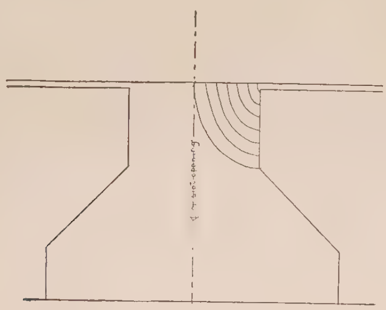

Fig. 3

the method more clearly. *a* is at 20 deg. on curve Fig. 5 and has an ordinate value of 100 per cent. This value is multiplied by the sine of 20 deg. to obtain the

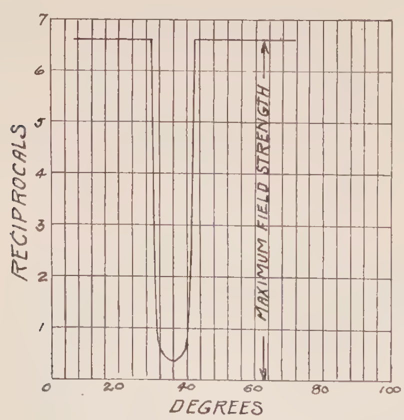

Fig. 4

corresponding ordinate for the sinusoidal field Fig. 6.

$$100 \text{ per cent} \times \sin 20 \text{ deg.} = 34.2$$

which is plotted at *a* Fig. 6. Likewise *b* at 36 deg. on Fig. 5 has a value of 5.05 per cent which, when multiplied by the sine of 36 deg., gives the corresponding ordinate for the sinusoidal field Fig. 6.

$$5.05 \text{ per cent} \times \sin 36 \text{ deg.} = 2.97$$

which is plotted at *b* Fig. 6.

Fig. 6 illustrates the effect of the slot openings on the

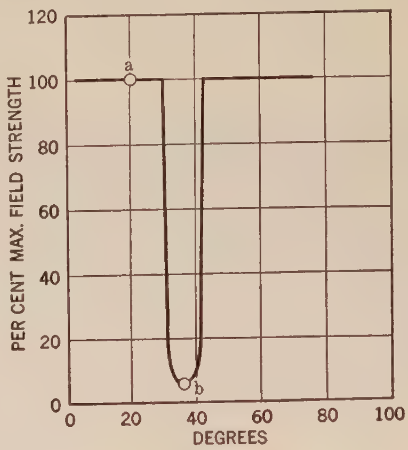

Fig. 5

field form of an induction motor. It should be noted that the indentations caused by the slot openings do not reach zero value. This, it will be understood, is due to the fringing and is what would be expected.

Since the direction of rotation of the harmonics is equally important as the kind of harmonics, it was necessary to find means for being certain of the direction of rotation of the harmonic fields as well as their order and magnitude, as compared with the direction of rotation of the fundamental. This was done by considering the fundamental as having advanced 18 electrical deg. clockwise with respect to the slotted element, which gives a new position of the indentations caused by the slot openings on the fundamental. To obtain he field form with the fundamental advanced 18 electrical deg. with respect to its former position, curve 5 with zero degrees taken at the 18 deg. point was mul-

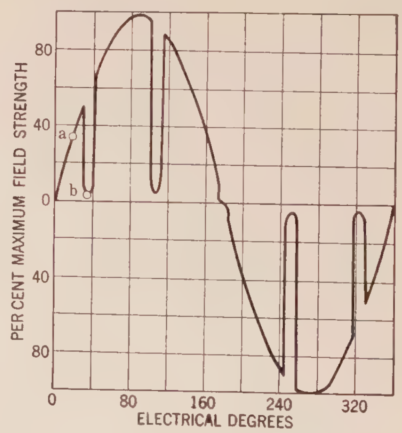

Fig. 6

tiplied by the sine curve in the same manner as previously explained and Fig. 7 obtained. If these two instantaneous field forms, Figs. 6 and 7 are analyzed for the various harmonics, the positions of each harmonic with respect to the fundamental in each case will give the rotation of the harmonics. This will be illustrated more fully later.

It is, of course, clear that the indentations caused

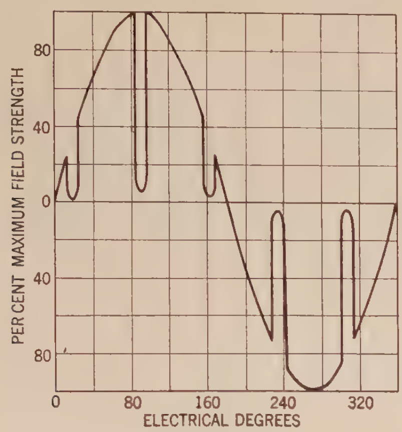

Fig. 7

by the slot openings will successively occur at all points in the fundamental in cyclical order. The task of analyzing the two instantaneous field forms, Figs. 6 and 7 for the higher harmonics was too tedious by mathematical methods and it was decided to re-plot these two instantaneous field forms on polar co-ordinates and analyze them on an available harmonic analyzer.

Figs. 8 and 9 show the instantaneous field forms Figs. 6 and 7 on polar co-ordinates. The analysis of

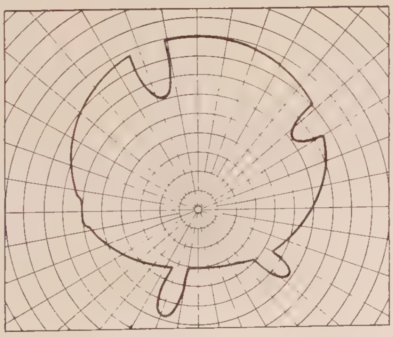

Fig. 8

these flux waves as obtained from the harmonic analyzer are shown in Table II.

An inspection of the values of the various harmonics shown in the Table brings out the fact that there are harmonics of appreciable magnitude as follows: 4th and 6th, 9th and 11th, 14th and 16th, 19th etc. . . . and that all other harmonics are zero or of negligible value. This fact may be represented mathematically as follows:

$$\text{Order of Harmonics} = k\,n \pm 1$$

where k equals any integer and n equals the number of slot openings per pair of poles.

The direction of rotation of the harmonics with respect to the fundamental was determined in the case of the 4th and 6th harmonics by plotting them on the instantaneous fields Figs. 6 and 7 from the values given in Table II as shown in Figs. 10 and 11. It will

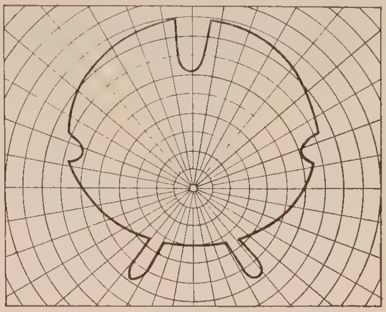

Fig. 9

be remembered that in the case of Fig. 7 the fundamental was advanced with respect to the slot openings 18 electrical deg. clockwise from its position in Fig. 6. Likewise Fig. 11 shows the conditions for the case of the fundamental having moved clockwise 18 electrical deg. from the position shown in Fig. 10. It is therefore evident that the positions of the 4th and 6th harmonics in Figs. 10 and 11 will indicate the direction of rotation of these harmonics.

In order to determine the direction of rotation of the 4th and 6th harmonics, the two instantaneous fields, Figs. 10 and 11 showing the 4th and 6th harmonics, were compared.

In the case of the 4th harmonic its maximum value occurs at 22½ deg. in the case of Fig. 10, whereas in

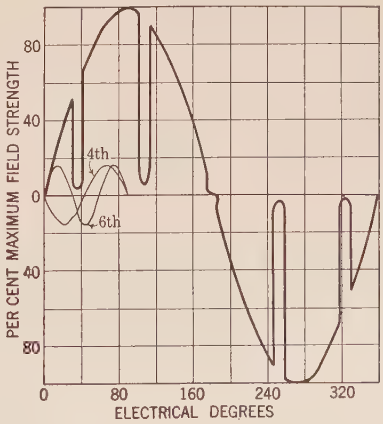

Fig. 10

the case of Fig. 11 it occurs at zero degrees. Now since the fundamental has advanced 18 electrical deg., the maximum of the 4th harmonic should be at plus 4½ deg. on Fig. 11 if the 4th harmonic did not move at all, that is, if the 4th harmonic were stationary in space. Since the maximum of the 4th harmonic on

Fig. 11 actually occurs at zero degrees it must have moved 4½ deg. contrary to the fundamental.

In the case of the 6th harmonic, its maximum value occurs at 15 deg. in the case of Fig. 10, whereas in the case of Fig. 11 it occurs at zero degrees. Since the fundamental has advanced 18 electrical deg., the maximum of the 6th harmonic should be at minus

TABLE II

N	Fundamental 1st. Position		*Fundamental 2d. Position	
	Sine	Cosine	Sine	Cosine
1	+ 93.8	0	94.1	0
2	0	− 1.1		
4	− 16.5	0	− 1.0	− 15.1
5	0	− 1.7		
6	+ 16.2	0	0	+ 16
8	0	− .8	0	− .7
9	+ 14.0	0	− 13.4	+ .6
10	0	+ .7	− .9	− .6
11	− 13.7	+ 1.1	+ 13.6	− .8
12	0	+ .8	− .6	0
14	− 10.7	− .8	+ .8	+ 10.3
15	0	0	0	+ 1.1
16	+ 10.7	− .7	− 2.0	− 10.3
17	+ .5	0	0	0
18	0	0	0	− 2.9
19	+ 7.3	0	7.5	0
20	0	0	+ .9	0

*In the second position the fundamental has moved to the right 18 electrical deg.

3 deg. on Fig. 11 if the 6th harmonic did not move at all, that is, if the 6th harmonic were stationary in space. Since the maximum of the 6th harmonic on Fig. 11 actually occurs at zero degrees, it has advanced 3 deg. with the fundamental.

Therefore, since we have assumed the fundamental to have clockwise rotation, the 4th harmonic will

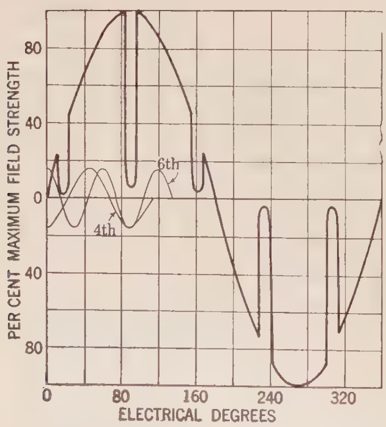

Fig. 11

rotate counter clockwise and the 6th harmonic will rotate clockwise.

The results of this graphical-analytical analysis shows that tooth harmonics are inherent and that tooth cusps are to be expected and that the tooth harmonics are of the order of an integer multiplied by the number of slots then increased and decreased by one.

After completing this investigation it occurred to the author that there ought to be a purely mathematical proof of this fact

$$\text{Order of Harmonics} = k\,n \pm 1$$

which could be obtained by a development of the series representing a rectangular wave to obtain the effect of slot openings.

This could be done by putting in place of α in

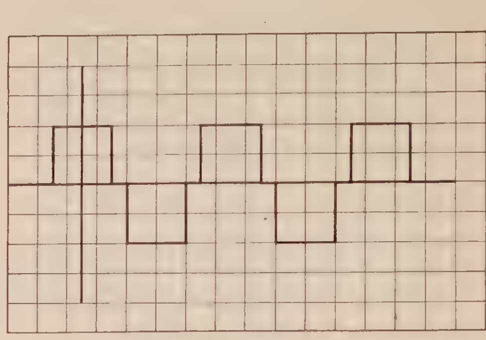

Fig. 12

Fourier's Series of the rectangular wave α plus θ and α minus θ and then adding like terms of the two series. This gives a wave as shown in Fig. 12, which can be changed to approach the form of the reciprocal wave shown in Fig. 5 by squaring the series representing this wave (Fig. 12) which gives the wave shown in Fig. 13 and which, it will be noted, is quite similar to Fig. 5. The difference between Fig. 5 and Fig. 13 is due to the

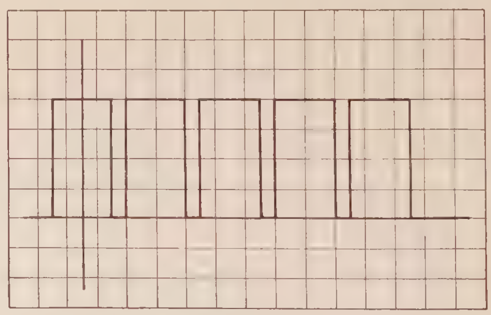

Fig. 13

fringing taken into consideration in the case of Fig. 5 which is the practical case. It will also be noted that the flux does not reduce to zero as in the case of mathematical demonstration. This difference between the mathematical case and the actual case would not affect this problem from a practical point of view.

This method of attacking the problem from a mathematical standpoint was proposed to Professor F. W. Lee, and his mathematical analysis follows in Part II of the complete paper.

Telephone Circuit Unbalances

Determination of Magnitude and Location

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Review of the Subject.—*The maintenance of telephone circuits in a high state of efficiency with respect to balance is important since unbalances contribute to crosstalk between telephone circuits and to noise when such circuits are involved in inductive exposures. Methods and apparatus are described which afford operating telephone companies means for maintaining their circuits in the condition of minimum practicable unbalance.*

Different types of unbalance are discussed, also their effects under different conditions of energization of the unbalanced circuit and neighboring conductors.

Methods are described for determining:

(1) *The general condition of circuits with respect to balance by crosstalk measurements from their terminals,*

(2) *The approximate location of unbalances along a line by measurements over a range of frequencies with a bridge at one end of the line, and*

(3) *The final location of unbalances by field measurements with an unbalance detector which may be operated by a lineman and does not usually require interruption of telephone service, except momentarily.*

Toll circuit office unbalances are briefly discussed and a special bridge for detecting, locating and measuring the unbalances of composite sets is described.

In an appendix is given a mathematical treatment of the bridge method for locating unbalances and a discussion of the necessity of terminating the circuits involved in the tests in their characteristic line impedances.

* * * * *

Introduction

Noise induced in a telephone circuit may arise in two different ways: First, by reason of dissymmetry in its relation to the inducing circuit, unequal voltages are induced in its two sides; Second, by reason of dissymmetry of its two sides in their relation to ground or to other telephone conductors, the voltage induced between the conductors and ground or along the conductors causes a voltage between the two sides of the unbalanced circuit. In the usual case, the voltages induced to ground or along the conductors are large compared to their differences, so that unbalances of the telephone circuits themselves have an important bearing on the problem of preventing noise in such circuits.

Dissymmetry with respect to the inducing circuit involves, of course, only that part of the disturbed circuit within the inductive exposure. This type of unbalance involves properties of the inducing circuit as well as of the telephone circuit and is therefore dealt with no further in this paper. Unbalances of the telephone circuits themselves may involve those parts of the circuit within the inductive exposure as well as the unexposed parts of the circuit and the terminal apparatus.

A telephone circuit would be balanced if its two sides had equal self and mutual impedances and equal admittances to ground and to other conductors in each elementary section of its length. In other words, the sides of a balanced circuit would be symmetrical in their relations to ground and to other nearby circuits. Such a circuit would have no difference in voltage between its two sides when equal voltages are induced between them and ground at any point of the circuit or when equal voltages are induced along them.

Abridgment of paper presented at the Pacific Coast Convention of the A. I. E. E., Pasadena, Cal., October 13-17, 1924. Complete copies to members on request.

It should be noted that this definition does not require longitudinal uniformity as a condition of balance. It merely requires that corresponding constants of the two sides of the circuit shall be equal at the same point and that this condition shall be satisfied for every point along the circuit. In practise it is neither necessary nor possible that this definition be rigorously satisfied, but a close approach to this ideal state of balance is obtained by transposing or twisting the conductors as a pair so that unbalances in neighboring sections of any circuit tend to neutralize, and by careful attention to the design and maintenance of the line and all connected apparatus.

Types of Unbalances

Unbalances of telephone circuits are of two general types. The first may be called self unbalances involving only the conductors of the circuit and ground, and the second, mutual unbalances involving also the other conductors. Thus, a self unbalance would exist even though all conductors except those of the circuit in question were removed to a great distance. Since in the usual case, both sides of circuits are constructed of wires of the same size and conductivity and at the same distance above the earth, there are no inherent self unbalances. Such unbalances are largely accidental and arise from such causes as defective joints, defective loading coils, broken insulators, tree leaks, or from dissymmetry in apparatus inserting series impedances in the circuit, or connecting admittances between the sides of the circuit and ground. Unbalances of this type do not depend upon the condition of surrounding circuits, although the noise effects caused by these unbalances may so depend.

The resultant unbalanced current or voltage in a circuit depends on both the self and mutual unbalances and upon the mode of energization and terminal impedances of both the circuit in question and neighbor-

ing conductors. In practise, it is not possible to measure the effects of the two types of unbalance separately.

It will be of interest to discuss briefly the relative importance of the two types of unbalance in their effects on noise and crosstalk with a view to examining the adequacy of various methods which may be used for measuring and locating unbalances.

Fig. 1 indicates a circuit which is perfectly balanced. This circuit consists of two similar conductors parallel to each other and to the plane surface of the earth, and removed to a great distance from all other conductors. Such a circuit can have only self unbalances, which in the practical case might consist of slight differences in conductor diameter, in conductivity and in sag, variations in the contour of the earth, resistance in joints and differences in series impedances or shunt admittances introduced by connected apparatus.

Fig. 2 shows the four parallel untransposed conductors of a phantom group. In this case the phantom would be unbalanced to each of its side circuits. If equal voltages were induced to ground or along each of the four conductors (similar apparatus being assumed connected to the two side circuits), a voltage would be caused in each side circuit, while no voltage would be caused in the phantom.

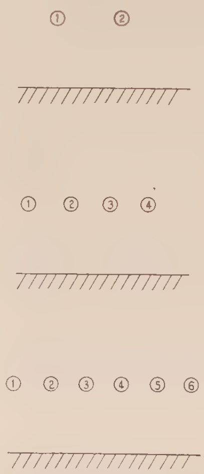
Fig. 3 indicates three circuits, each consisting of two similar untransposed parallel conductors. In this case, assuming perfect construction, each circuit would have no self unbalances. However, no one of the circuits would be symmetrical in its relation to each of the other conductors. If equal voltages were induced to ground or along the two sides of circuit 3-4, and both 1-2 and 5-6 were left either free or connected to earth, no voltage would be caused between the sides of 3-4. The same would be true if equal voltages were induced along all six of the conductors or from them to ground. Voltages would be caused, however, in both circuits 1-2 and 5-6 under this condition. A voltage would be set up in circuit 3-4 if equal voltages were induced from its sides to ground or along its sides, while different conditions were imposed on circuits 1-2 and 5-6 as, for example, if 1-2 were isolated and 5-6 connected to ground.

In the practical case, involving multi-wire lines, none of the circuits on the line are inherently balanced in respect to their mutual relations to all other conductors. A close approximation to such balance is obtained, however, by means of transpositions whereby the unbalances existing in one section are neutralized by those in a nearby section of line. Thus, transposition errors are a source of mutual unbalances.

In any practicable method of determining unbalances, the current or voltage measured in the circuit, or the impedance of a compensating unbalance which would reduce the voltage and current to zero, are complicated functions of the location, character and magnitude of the self and mutual unbalances, and the mode of energization and terminal impedances of the test circuit and neighboring conductors. The effects of mutual unbalances are particularly dependent upon the energization and impedance conditions of the neighboring conductors.

Methods of Energizing Circuits

If unbalances are measured by energizing a superposed circuit consisting of the two sides of the circuit in parallel to ground, leaving other conductors free, and observing the unbalanced current, the effect of transposition errors will usually be small as compared to even small self unbalances which might be present. The current due to the mutual unbalances is, in this case, a secondary effect, because of the relatively small amount of power in each of the neighboring conductors. The current and voltage in the energized superposed circuit induce current and voltage in circuits composed of the neighboring conductors and ground, since transpositions are not effective in reducing induction between grounded



Figs. 1, 2 and 3

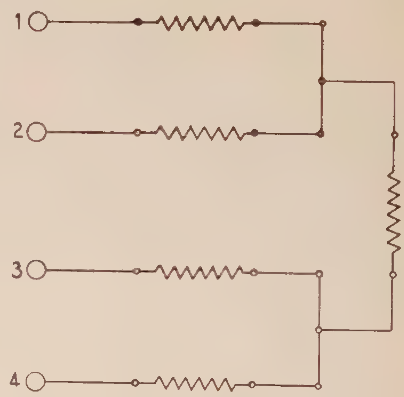


Fig. 4—Simple Network for Terminating a Phantom Group

circuits. These induced currents and voltages in the individual neighboring conductors are much smaller than the original current and voltage in the conductors of the superposed circuit. The induced currents and voltages in turn react by induction upon the current and voltage in the superposed circuit, and because of the transposition error this reaction is unsymmetrical, resulting in a current and voltage in the metallic circuit which forms one side of the superposed circuit.

If unbalances are measured by applying with respect to ground, the same voltage to all of the conductors on the line, the current set up in the test circuit due to a transposition error will no longer be a secondary effect, since the voltages and currents in each of the neighboring conductors will then be of approximately the same magnitudes as those in the conductors of the circuit whose unbalances are being determined. In this case the effect of a transposition error is increased relatively to that in the first case and becomes comparable in importance to the effect of a self unbalance.

If, however, the unbalances are measured by determining the crosstalk between the circuit in question and its phantom, with certain exceptions noted below the transposition error is also a primary effect. The current and voltage in closely adjacent conductors (those of the other side of the phantom) are of the same magnitude, but opposite in phase, as those in the conductors of the circuit whose unbalances are being measured. In this case the effects of a transposition error are probably more important as compared to those of self unbalances, than if all conductors of the line were energized simultaneously at the same voltage.

In an inductive exposure the voltages to ground and longitudinal currents of all conductors of the various circuits on the line are of the same order of magnitude. Consequently, the effects of transposition errors in the unexposed sections of line on the resultant unbalanced current in a circuit are more important than if this circuit alone were energized.

In maintaining telephone circuits in a condition of satisfactory balance from the standpoint of noise it is necessary that the methods employed to detect and locate unbalances be such as to cover all types of dissymmetry which contribute to noise. In order that all unbalances might be given proper weight in the measurement, it would be desirable, of course, to energize the test and the neighboring conductors in the same manner, relatively, as when the energization is due to inductive exposures. This is, however, impracticable.

If the methods used are sensitive enough to detect all sources of unbalance on any part of the circuit, large enough to contribute to noise or crosstalk, it is not essential that they cause the same relative effects on the measurements as on the noise or crosstalk. As brought out in the previous discussion, the important sources of unbalance contributing to noise are defects in line and connected apparatus (self unbalances) and transposition errors (mutual unbalances). With the exception of vertical pole-pair phantom groups all such unbalances in side circuits contribute to crosstalk in the phantom and this crosstalk may be used therefore as a measure of unbalance of side circuits. Transposition errors in vertical pole-pair phantom groups have very little effect on phantom-to-side crosstalk. Unbalances may exist in any phantom group which will not contribute to crosstalk but which will contribute to noise in the phantom circuit. Similarly, a non-phantom pair may be unbalanced for noise, but these unbalances may not cause appreciable crosstalk to any existing circuit. However, in all these cases where crosstalk is not caused in any existing circuits, special superposed circuits may be set up for test purposes in which these unbalances will cause crosstalk.

A simple arrangement for such a purpose is a superposed circuit having for one side the conductors in parallel of the circuit under test, and ground for the other. As already stated, however, transposition errors cause relatively small effect on crosstalk in this case. If, instead of the ground, the conductors in parallel of another phantom or non-phantomed pair, preferably on the same crossarm, be used to form the superposed circuit, transposition errors will be indicated as well as the self unbalances, in the same manner as in the case of crosstalk between a horizontal phantom and its side.

The methods which are in use in maintaining balanced telephone circuits in the plant of the Bell System utilize the crosstalk to metallic superposed circuits made up as above described as a criterion of unbalance. These methods provide means for indicating the unbalanced condition of a circuit by measurements of crosstalk made at its terminals; for obtaining an approximate location of sources of unbalance by measurements from one end of the circuit; and for securing a definite location of the unbalance by local measurements along the circuit, these latter measurements not involving opening the circuit.

In general, the magnitude of the crosstalk measured between two circuits will depend upon the frequency of the testing current used. When the source of the crosstalk is a capacitance or inductance unbalance, this is due to the increase in crosstalk with frequency. Also, when more than one unbalance is present, the crosstalk currents caused by the different unbalances add at some frequencies and subtract at others. Thus a single-frequency crosstalk measurement is not a reliable indication of the general condition of the circuit as regards unbalances. Crosstalk measurements must, therefore, be made at a number of single frequencies or with a source of energy of complex wave form.

In practise both schemes are used, a complex wave being employed to obtain an indication of the general condition of the circuit and a number of single frequencies being employed successively to determine the location of unbalances.

Termination of Circuits

It is desirable in making unbalance or crosstalk tests that the measurements be made in such a way that the effect of any given unbalance on the crosstalk or equivalent unbalance of the circuit be independent of the length of circuit tested. In order to obtain this result, reflected waves from the distant ends of the circuits must be minimized. This is accomplished by terminating the circuits in networks whose impedances approximately equal the impedances of infinite lengths of the circuit. The precision with which it is necessary for these network impedances to simulate the characteristic line impedances depends upon the attenuation losses in the section of line under test. If the section be long enough terminations are unnecessary. Three types of network have been developed for use in these measurements which simulate the line impedances to different degrees of precision.

The first type of network, which is shown by Fig. 4, consists of a group of carefully balanced resistances. It is for use principally on cable circuits but may also be

used on open-wire circuits for the crosstalk tests to indicate the general condition of a circuit as to unbalances. More accurate terminations are required for the measurements to obtain unbalance locations unless the section tested is long.

A second type of network is shown by Fig. 5 which is more particularly adapted to tests on open-wire circuits. In this case the circuit under test and the superposed circuit used as the reference are terminated by a

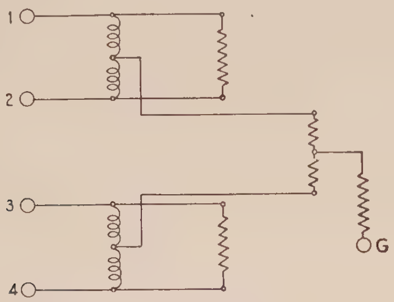


Fig. 5—Network for Terminating Simultaneously All Circuits of a Phantom Group. Binding Post G may be Connected to Four Wires in Parallel of a Nearby Phantom Group

carefully balanced retardation coil and resistances, rather than by resistances alone. Through the use of keys it is possible to arrange for terminating circuits of various types including both non-loaded and loaded circuits.

The third type of network shown by Fig. 6 is used when a more accurate termination than is possible with the other types is required. This network is usually

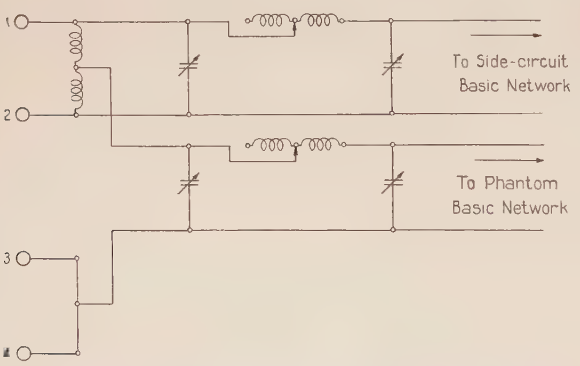


Fig. 6—Adjustable Building-Out Section. Schematic Circuit when used for Building-Out Simultaneously Phantom and Side Circuit

required only in connection with measurements made at one of the circuit terminals to locate unbalances. By the use of this adjustable "building-out section" in conjunction with an adjustable "basic network," it is possible to terminate open-wire circuits of any type and in the case of loaded circuits, at any point in the loading section, with a minimum of departure from the correct impedance. The networks of this third type are similar to those used in securing two-way repeater operation.

Crosstalk Set

The crosstalk set shown by Fig. 7 is used for measuring crosstalk between telephone circuits at frequencies within the voice range. This figure shows the schematic circuit arrangement when measuring "near-end" phantom-to-side crosstalk. "Near-end" crosstalk occurs when the talking and listening are done at the same end of the line. In the left-hand position of the switch, a source of testing current is connected to a crosstalk meter, which is a simple form of potentiometer. In the right-hand position the switch is connected to transformer *A*, the impedance ratio of which is adjustable, so that the impedance of any standard type of telephone circuit as measured through the transformer can be made approximately equal to that of the crosstalk meter. With this arrangement the power into the transformer is approximately equal to that into the crosstalk meter, particularly when the impedance of the source of current is about equal to that of the crosstalk meter.

Transformer *B*, also an adjustable impedance ratio

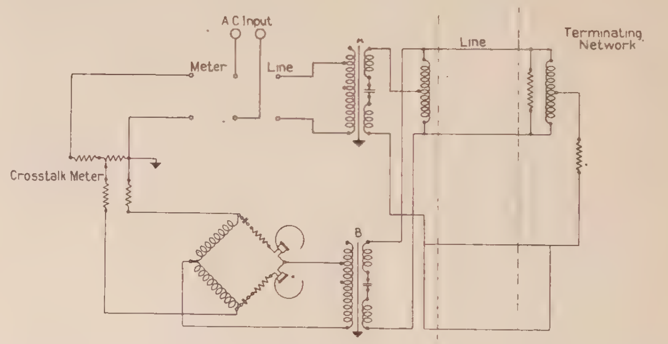


Fig. 7—Crosstalk Set. Schematic Circuit when Measuring Near-End Phantom-to-Side Crosstalk

transformer, is designed to permit a disturbed circuit of any standard type to deliver about the same power to the crosstalk set as it would deliver to a long circuit of its own type. Both transformer *B* and the crosstalk meter are connected to a network of resistances, condensers, receivers and a retardation coil, arranged in the same general manner as the four arms of a Wheatstone bridge. The branches to which the crosstalk meter and the disturbed circuit are connected have practically no effect upon each other and the disturbed circuit may therefore remain connected to the receivers while the source of disturbing current is switched to the crosstalk meter, thereby allowing the noise from the disturbed circuit to remain constant. This arrangement greatly facilitates accurate crosstalk comparisons on noisy circuits.

Measurements are made by listening to the crosstalk on the disturbed circuit and then to the tone produced by the current from the crosstalk meter, adjusting the latter until the two are equal. The reading of the scale on the crosstalk meter then represents the crosstalk

between the circuits under test expressed in crosstalk units. The crosstalk unit is chosen to indicate a convenient relation between power sent into the disturbing circuit and that received from the disturbed circuit.

Bridge for Locating Unbalances

When the measurement of crosstalk indicates that the unbalances of the circuit are greater than the allowable limit, measurements may be made with an impedance unbalance bridge to obtain an approximate location of the unbalances. The method is adapted from a similar one for locating irregularities in the impedances of metallic telephone circuits which interfere with repeater operation. It may be usefully applied only to circuits of considerable length, approximating 50 miles or more of open wire. Shorter lengths may be tested in cables. The bridge is shown in schematic form in Fig. 8 connected, with a phantom circuit as a superposed reference, to locate the unbalances of a side circuit.

The bridge is made up of a pair of equal ratio arms with a fixed inductance and resistance which are con-

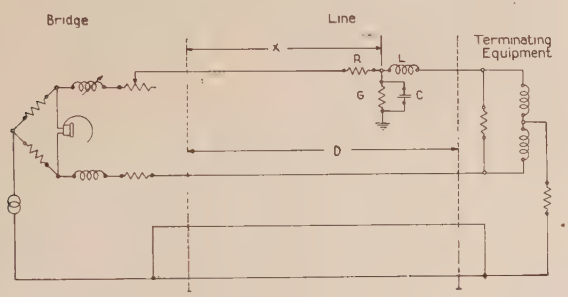


Fig. 8—Impedance Unbalance Bridge. Connected for Determining Phantom-to-Side Unbalance

nected in series with one side of the line and an adjustable resistance and inductance which are connected in series with the other. It is thus possible to adjust the bridge for balance whether one side of the line or the other is higher in impedance without having to reverse the bridge terminals with respect to those of the line. A telephone receiver is used as a detector and an adjustable-frequency vacuum-tube oscillator as a source of energy.

The method consists in balancing the bridge at a number of frequencies at definite intervals in the range from 200 to 2000 cycles and determining the magnitude and sign of the resistance and inductance unbalances which must be inserted in the bridge in order to compensate for those in the line. The values of equivalent resistance and inductance unbalance thus obtained are plotted as functions of the frequency. From these curves a location may be determined for the unbalance or unbalances if their number is not too great.

In principle this method is based upon the finite velocity of phase propagation of electric waves along the reference circuit to the unbalance and back along the circuit under test to the bridge. Thereby, the wave of unbalanced current received at the bridge from the distant unbalance is retarded in phase with respect to the current sent into the reference circuit, in addition to any localized phase shift produced by this unbalance. Only a localized phase shift occurs in the crosstalk or unbalance current set up by the compensating unbalance which is inserted in the bridge. Therefore, the compensating unbalance must be of such a character that its phase shift differs from that produced by the distant unbalance by an amount equal to the phase retardation caused by the finite velocity of phase propagation along the circuits. This phase retardation for a given location of unbalance depends on the frequency of the test current, since the distance to the unbalance measured in wave lengths varies inversely with the frequency. By measuring over a range of frequencies, the localized phase shift may be eliminated and that frequency ascertained for which the total distance of propagation to and from the unbalance is equal to one wave length. Thus its approximate location may be determined if the velocities of phase propagation on the two circuits be known. The method is based upon the assumption that the velocities of phase propagation and localized phase shifts are substantially independent of the frequency. These assumptions hold sufficiently well over the necessary working range of frequencies, and for the types of unbalance usually encountered. A mathematical discussion of the method is given in an appendix.

As an example of the method, consider a non-loaded open-wire phantom group in which the velocities of phase propagation are 180,000 mi. per sec. Let it be assumed that a series resistance unbalance is present 100 miles from the bridge. This is a wave length at 1800 cycles. It is various fractions of a wave length at other frequencies as indicated by the table below. This table indicates also the phase of the current in the reference (phantom) circuit at the position of the unbalance and that of the crosstalk current when propagated back over the circuit under test to the bridge, with respect to the current sent into the reference circuit at the bridge.

f	Fraction of Wave Length	Phase of Current in Reference Circuit at Unbalance	Phase of Crosstalk Current at Bridge Due to Unbalance at $L = 100$
225	1/8	−45 deg.	−90 deg.
450	1/4	−90 deg.	−180 deg.
675	3/8	−135 deg.	−270 deg.
900	1/2	−180 deg.	0 deg.
1125	5/8	−225 deg.	−90 deg.
1350	3/4	−270 deg.	−180 deg.
1575	7/8	−315 deg.	−270 deg.
1800	1	0 deg.	0 deg.

If unbalance be inserted at the bridge to compensate for that in the line, it is evident that at 900 cycles and at 1800 cycles this compensating unbalance must be of the same character (resistance in this case) as that out on the line and on the opposite side of the circuit.

At 450 and 1350 cycles the compensating unbalance will also be resistance but in the same side of the line. At 225 and 1125 cycles the compensating unbalance must be an inductive reactance in the same side of the line and at 675 and 1575 cycles an inductive reactance in the opposite side of the line. The values of equivalent unbalance are plotted on Fig. 9, changes in attenuation with frequency being neglected. It will be seen that periodic curves are obtained having a frequency interval of 900 cycles. This is the frequency for which the distance out to the unbalance and back corresponds to a full wave length. The rule for cases in which the velocity of phase propagation is the same in the test and reference circuits, is expressed by the formula:

$$X = \frac{V}{2 f_i}$$

where X is the distance to the unbalance, V is the velocity of phase propagation and f_i is the frequency interval of the curves.

When more than one unbalance is present, the curves obtained are the resultants of the simple periodic curves

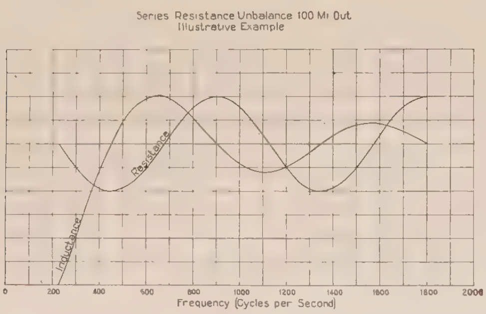


Fig. 9—Equivalent Impedance Unbalance. Non-Loaded Open-Wire Side Circuit

which each of the individual unbalances would give if present alone. It is evident that when there are a large number of unbalances present the curves become very difficult of analysis. As a rule, the periods corresponding to the several unbalances present have no common integral multiple within the range of frequencies tested. Analysis by the methods used for analyzing periodic waves is therefore not possible. While the curves are thus made up of periodic waves they are not in themselves periodic.

When the several unbalances differ considerably in size it is often possible to make an analysis by inspection locating initially the largest unbalance. After this one unbalance has been located and cleared a second set of curves may be made which will now contain one less unbalance than before and will be correspondingly simpler to analyze. Where the unbalances are of approximately the same size but at a considerable distance apart they may often be separated by arranging to terminate the circuit at some intermediate point which will include one or two of the unbalances and eliminate the others. When the nearer unbalance has been located and cleared the longer section may be tested and the more distant ones located.

Fig. 10 shows curves taken on a cable circuit before and after removing a series resistance unbalance. Figs. 11 and 12 show curves taken on open-wire circuits, the former on a phantom circuit, before and after removing an inductance unbalance caused by the use of the wrong type of loading coil on one of the sides, and

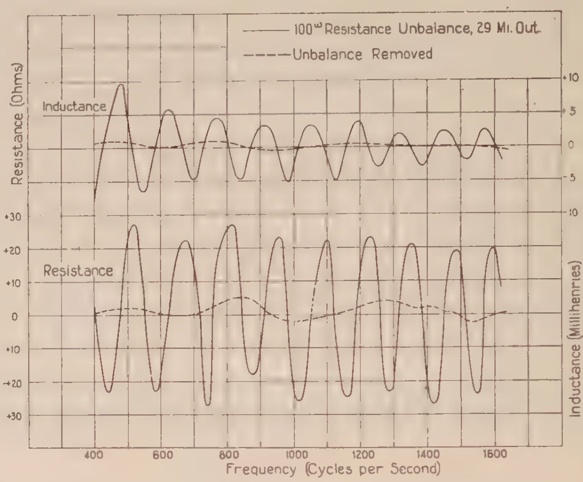


Fig. 10—Equivalent Impedance Unbalance. Heavy-Loaded No. 19-Gage Cable Side Circuit

the latter on a side circuit, before and after correcting a transposition error. It will be noted that equivalent resistance and inductance unbalances are plotted rather than equivalent resistance and reactance unbalances. This is done both because of greater convenience and because the former curves are more easily analyzed. The reactance in the bridge is introduced by an inductometer from which inductance unbalance may be read directly. If reactance were desired it would have to be calculated from the inductance setting. When the unbalance is a resistance, its effect is approximately independent of frequency and an equivalent resistance curve is obtained which is periodic while the inductance curve is the product of a periodic curve and of a curve

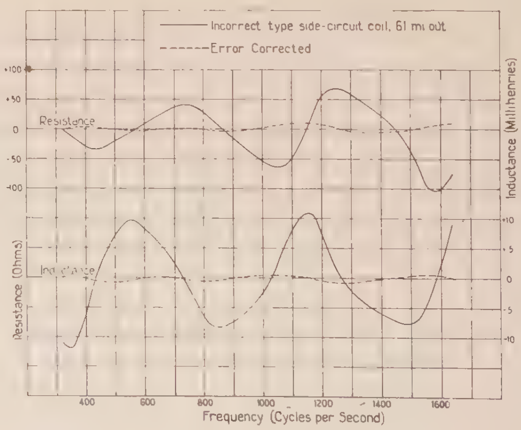


Fig. 11—Equivalent Impedance Unbalance. Loaded No. 8 B. w. g. Open-Wire Phantom Circuit

whose ordinates are inversely proportional to frequency. When the unbalance is series inductance or shunt capacitance, the effect increases with frequency and an equivalent inductance curve is obtained which is periodic while the resistance curve is the product of a periodic curve and of a curve whose ordinates are directly proportional to frequency. Thus for both types of unbalance one periodic curve is obtained, while if reactance were plotted, only resistance unbalances would yield such curves. These curves are, of course,

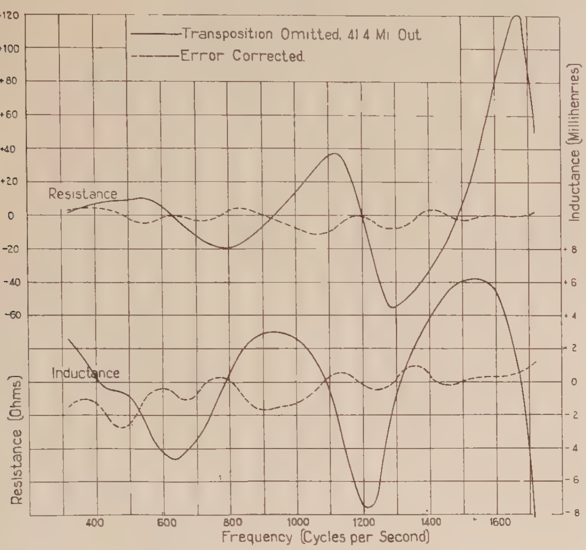


Fig. 12—Equivalent Impedance Unbalance. Loaded No. 12 N. B. S. G. Open-Wire Side Circuit

modified somewhat by the variation of attenuation with frequency but usually this effect is too small to introduce much difficulty into the analysis.

From the information given by these curves it is usually practicable to locate a single unbalance or one considerably larger than any other existing on the circuit, within one or two 8-mile transposition sections. Series unbalances in loading coils or immediately adjacent thereto may usually be located at the correct load point. To locate definitely transposition errors and resistance in joints, in either loaded or non-loaded lines, it will often be necessary to cover two 8-mi. transposition sections with the unbalance detector as described below.

Unbalance Detector

This unbalance detector consists of two parts, known as the sending and receiving sets. These parts are bridged to a circuit at points on either side of the suspected point of unbalance as indicated by the bridge, it being unnecessary to open the line wires. A test with the apparatus shows definitely if the circuit is unbalanced between the points at which the two parts are connected. It does not show the location of the unbalance. If an unbalance is found to exist in the section of line between the sets, they are moved closer together and the test repeated, this process being continued until the unbalance is reached. Fig. 13 shows a schematic circuit of the two parts of the set as arranged for testing side circuits of a phantom group. The entire equipment can be operated by one person.

The sending set is shown as a single-frequency generator connected across the phantom or other reference circuit, the sides being short-circuited. The receiving set consists essentially of two phantom coils, two potentiometers and a receiver. The single-frequency generator causes a current in the phantom circuit in both directions from the point of connection. If the four wires are perfectly balanced, the currents in them will be equal in magnitude and phase if the potentiometers are set so that the resistances on the two sides of the contacts are equal. In this case no sound will be heard in a receiver when connected to either of the phantom coils.

If a resistance unbalance X is present in wire 1, the impedances of wires 1 and 2 will be unequal and the currents in them, therefore, unequal. In this case a tone will be heard in the receiver. By adjusting the potentiometer contact until the unbalance of the potentiometer offsets the effect of X, the currents in the line windings of the coil will be approximately equal and the currents in the receiver consequently small. The reading of the potentiometer can, therefore, be used to indicate the condition of the circuit between the sending and receiving sets. When a transposition error is present the unbalance caused is indicated by current in the receiver which it is not possible to balance out by adjusting the potentiometer.

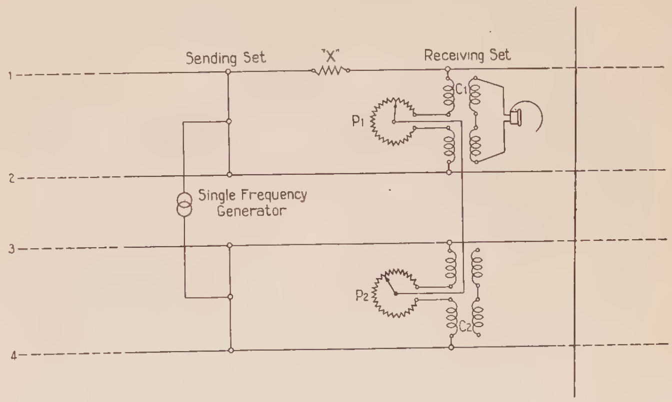


Fig. 13—Unbalance Detector. Schematic Circuit when Testing Side Circuits of Phantom Group

The actual circuit of the apparatus differs somewhat from that shown in the schematic circuit. The oscillator is not permanently connected across the circuit to be tested, but is arranged so that it can be connected to it by relays controlled by a key in the receiving set. When the key is not operated, the oscillator is not in operation and the sending set is connected to the circuit in such a manner as not to interfere with the use of the circuit for telephone purposes.

In addition to its use for finally locating an unbalance

whose approximate location has been determined by the impedance unbalance bridge, this unbalance detector may be used also when the length of line is too short to justify the use of the bridge method and when the number of the unbalances makes the complexity of the curves too great for even an approximate location with the bridge. In these latter cases the entire length of circuit may be covered with the detector.

Office Unbalances

The normal equipment of a toll telephone circuit includes a transformer or repeating coil which isolates the telephone apparatus from the line and from the telegraph apparatus. This transformer interrupts the transmission of longitudinal currents through the telephone office apparatus and prevents impressing noise voltage to ground on the unbalances of such apparatus. Apparatus used for superposing direct-current telegraph and carrier-frequency channels on the telephone

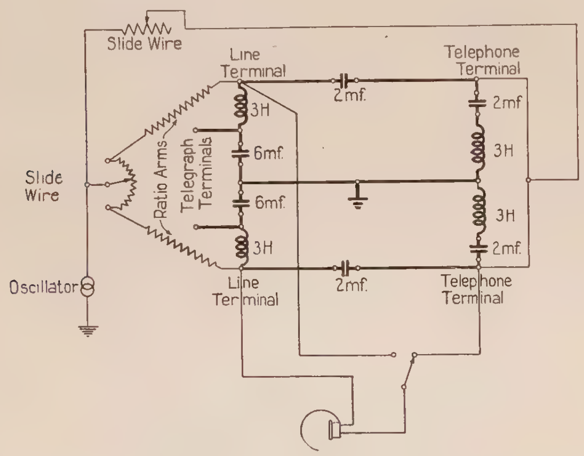


Fig. 14—Composite Set Bridge. Schematic Circuit when Measuring Unbalance of Telegraph Branches of Composite Set. Heavy Lines Show Composite Set

circuit is on the line side of this transformer and is therefore subjected to the action of longitudinal currents and voltages to ground. The line-filter set used for separating the carrier channels from the voice-frequency and d-c. telegraph channels has series and shunt branches in the two side circuits of a phantom group but no branches to ground. Unbalances in this set have a more important effect on crosstalk than on noise. Unbalances in the line-filter set may be detected by the use of the crosstalk set, connecting it to the office side of the filter with a terminating network on the line side.

The composite set used for superposing the d-c. telegraph channels on the telephone circuit has both series branches and branches connected from each wire to ground. For this reason, and because it is more generally used in the toll telephone plant than the line-filter set, special methods and apparatus have been developed for conveniently determining its condition from the standpoint of balance and for locating and determining the magnitude of such unbalances as may exist.

Some of the parts of the composite set can be tested with a simple slide wire bridge. Other parts, particularly the telegraph branches, cannot be so tested. By means of a special arrangement in the composite set bridge, the device which has been designed for rapid testing of the parts of a composite set as well as the whole set, the telegraph branches can be accurately measured without disconnecting any of the parts. A schematic circuit of the bridge, as arranged for testing these branches, is shown in Fig. 14. A simple slide wire bridge is connected across the line terminals of the composite set. A source of testing current is connected between the moving contact on the slide wire and ground. In order to prevent unbalances in the other branches of the composite set from affecting the measurements, the source of testing current is connected through an adjustable resistance to the telephone terminals. By simultaneous adjustment of this resistance and the slide wire of the bridge, it is possible to bring the line and telephone terminals to approximately the same potential. If this be done, the effect of the remainder of the composite set is eliminated and a measurement with the receiver connected across the ratio arms in the usual manner gives the unbalance of the telegraph branches alone. A receiver connected across either of the series condensers, as indicated, is used to determine when the line and telephone terminals are at the same potential, no sound being heard when this condition obtains.

Conclusion

While the effect of unbalances of a telephone circuit in contributing to noise depends much upon how and where the circuit is energized and on the energization and condition of other nearby telephone circuits, the test methods which have been devised permit the detection of all important unbalances which may contribute to noise. All of the apparatus for applying these methods has been standardized and made up in portable form for convenience in field testing. Much of it has been in use for several years.

The development of this apparatus, and of the methods outlined, provides the operating telephone companies with effective means for detecting faults of balance, and for maintaining circuits in a high state of efficiency from this standpoint. These methods are particularly applicable to toll circuits but some of them can also be applied to local circuits where necessary. This is important in minimizing crosstalk among telephone circuits and noise interference when such circuits are raised above the potential of the earth by induction from neighboring power circuits.

Further investigations of unbalances are in progress to determine more definitely the relationship between the magnitude and location of unbalances and their resultant effect at the circuit terminals when the circuits are energized inductively.

ACKNOWLEDGMENT

Credit is due chiefly to F. H. Best and P. W. Blye for carrying out the work leading to the development in practical form of the apparatus described. The authors wish to express their appreciation to them and also to H. M. Trueblood, A. G. Chapman and other colleagues for many helpful suggestions and criticisms received during the preparation of this paper.

Brief Synopses of Papers Presented During 1924

Available only in Pamphlet Form

FREE CONVECTION OF HEAT IN GASES AND LIQUIDS-II*

CHESTER W. RICE
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The present paper is an extension of my earlier work which was found necessary in order to account for the observed convection for both large and small temperature differences.

General expressions are developed, by the method of dimensions, which enable us to calculate the convection from any system of similar bodies when the three undetermined constants K, m, and n have been experimentally determined.

The available experimental data for horizontal and vertical cylinders, spheres and plane surfaces have been analyzed and the results expressed in the form of simple equations.

CURRENT-LIMITING REACTOR CHARACTERISTICS†

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Member, A. I. E. E.
Electrical Engineer Metropolitan Device Corp., Brooklyn, N. Y.

To prevent in large generating and distribution systems the possible concentration of enormous amounts of electrical energies at certain critical points, makes the extensive use of the current-limiting reactor a necessity.

Connected reactor installations of 30,000 to 50,000 kv-a. capacities are not unusual anymore.

Aside from the many important issues involved in the generating system as a whole by the reactor equipment, the reactor itself became a very important factor.

After the paramount issue of short-circuit protection is disposed of, a number of minor features are to be considered in the reactor design.

The general characteristics of the various winding types, the circuit connections affecting the true reactance values, current distributions, throughout a multilayer reactor and conductor efficiencies are considered.

Creeping due to heating of the conductor is evaluated.

Attention is called to the fact, that the attraction or repulsion of the turns or layers within a reactor depends upon the layer or turn interconnections.

The mechanical forces upon the conductor during short-circuit stresses are investigated and an approximate expression is given for their calculation.

TRANSIENT PERFORMANCE OF ELECTRIC ELEVATORS

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Member, A. I. E. E. — Associate, A. I. E. E.
Otis Elevator Company — Otis Elevator Company
New York, N. Y. — New York, N. Y.

The investigation of transient conditions is vitally important in elevator engineering, both electrical and mechanical. In no other method of human transportation are traveled distances so short and speeds and loads so frequently varied. Passengers must be hoisted and lowered safely and expeditiously. Landings must be accurately made. The elevator is consequently a machine that is very sensitive to transient effects and the entire apparatus must therefore be designed on the basis of transient analysis.

Pure mathematical determination of elevator transients is evidently both difficult and laborious. In some cases it is impossible because the functions are unknown. Graphic methods of analysis lead to a much clearer understanding of the reasons for transient conditions, thus considerably aiding development.

Interdependent mechanical and electrical transients of a hoist system are first developed in the following. Then separate mechanical and electrical transients are considered. Finally, temperatures of the electrical apparatus, resulting from elevator operation in service are determined.

The basic method of transient determination used in this paper is to plot one or more curves representing

*Presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8. 1924. An abstract of this paper was presented at the Cincinnati meeting of the Am. Phy. Soc. Dec. 1923. See also discussion Jour. A. I. E. E., Dec. 1923. A companion paper on Forced Convection of Heat in Gases and Liquids II will be presented at the April meeting of the Am. Chemical Society.

†Presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chicago, Ill., June 23-27, 1924.

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Presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

integrals which each contain a single variable and which, when integrated, will give the desired solution. These integrals are evaluated between limits by measurement of the areas defined by these curves.

Methods of determining elevator transients of speeds, distances, currents, voltages, powers, forces and fluxes, are developed in this paper by means of this system of graphic integration.

SHORT-CIRCUITS OF A-C. GENERATORS-II*

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Power Engineering Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

At the mid-winter convention of the A. I. E. E. in February, 1924, the writer presented a paper on the maximum instantaneous values of the currents delivered by alternating-current generators under different short-circuit conditions. A summarized table was given for the maximum values of the short-circuit currents for different winding combinations of an ideal generator on the basis of a constant field flux, and that the short-circuit occurs at the instant the axis of the field winding coincides with the axis of the particular portion of the armature winding under consideration.

In the present paper, a similar analysis is given for the magnitude and variation of magnitude of the short-circuit currents during the transient period, that is, during the time the currents vary from the maximum to the sustained values.

SINGLE-PHASE MOTOR-TORQUE PULSATIONS*

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This article gives results of a study of the vibrations of small single-phase induction motors, with a view to determining their causes and eliminating the noise which they produce. The possible sources of such vibrations were analyzed, and an experimental study was made in which the principal cause was definitely determined to be the double-frequency variation of the electro-magnetic torque developed by the motor. This variation of torque is fairly obvious when it is considered that the power input to the motor is pulsating and the output is uniform, but it was found that the torque variation at no-load was also very pronounced, a fact which does not seem to have been previously described. A description of the experiments made, a theoretical analysis of the torque variations, and a comparison of test with calculated results are given.

Presented at the Northeastern District Regional Meeting of the A. I. E. E., Worcester, Mass., June 4-5, 1924.

CURRENT-LIMITING REACTORS THEIR DESIGN, INSTALLATION AND OPERATION

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The essential features in the design, installation and operation of current-limiting reactors are pointed out. The application of reactors to different circuits is not treated because a number of good papers dealing with this subject has been presented at Institute meetings.

Design. A current-limiting reactor should have low reactance at low currents and high reactance at high currents. Such a reactor has been developed and is known as the "saturated core" reactor. It has not been used as yet for current-limiting protection to any extent. A reactor having an iron core and only an a-c. winding gives a drooping voltage-ampere characteristic and, therefore, is not suitable for current-limiting protection. Reactors with air cores have straight line volt-ampere characteristics and, therefore, are well adapted for this protection.

Since the only function of current-limiting reactors is to limit the current during short circuits to safe values, they should be capable of performing this function when other apparatus is being destroyed, due to excessive current. For this reason, heat resisting materials should be used for holding and insulating the conductor of a reactor. A useful formula is given for determining short-circuit temperature rises.

A current-limiting reactor functions as such only when there are short circuits on the system. Short circuits are almost sure to be preceded or accompanied by voltage disturbances of abnormal value. Therefore, the insulation factor of safety in a reactor should be relatively high.

Reactors with shunting resistors give to the system in which they are placed, the protection from over-voltage that the resistors afford and are, therefore, to be recommended.

Reactors are subjected to internal magnetic forces due to the current in the reactor itself and to external magnetic force due to the field between adjacent reactors. A method is given for calculating the magnitude and direction of the internal forces. Tests show that the peak magnetic force should be used in calculating the strength of the conductor.

The direction of the external forces is discussed and reference is made to H. B. Dwight's formulas for calculating their magnitude. Tests show that the stresses on the members which support the reactor against the external forces depend in a decisive way upon the ratio of the mechanical frequency to the electrical frequency.

Presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chicago, Ill., June 23-27, 1924.

Installation. The installation of reactors is considered from the following view points.

I. Arrangement.
II. Compartments.
III. Bracing and Securing in Place.
IV. Support of the Leads.
V. Ventilation.

Operation. In general, reactors require very little attention in service, but no effort should be spared to keep them free from foreign conducting material. Loose magnetic material such as nails, etc., are particularly dangerous because the magnetic field of the reactor during a short circuit will pick up nails at quite a distance from the reactor and draw them into the winding. Tests show that such foreign material lodged in the winding causes the reactor to instantly arc over during a short circuit.

THE FLASHING CHARACTERISTICS OF SERIES AND COMPOUND-WOUND MOTORS*

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Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

This paper, to a certain extent, is in the nature of a log covering several years' test on a line of dynamotors. The flashing characteristics of series and compound-wound motors are discussed with special reference to these tests. The principles derived from the study of these machines have, however, been applied successfully to other motors. Machines of this type are apt to have a critical flash point, depending upon the constants of the electric and magnetic circuits. The oscillograph has been used to determine the best relation of shunt to series field for a given difference of speed between full load and no load. Methods of improving the flashing characteristics of a given machine are discussed. In some cases it is shown that a damper on a series-wound motor gives better flashing characteristics. An attempt to explain the nature of a flashover on a d-c. machine is made.

POTENTIAL GRADIENT AND FLUX DENSITY*

Their Measurement by an Improved Method in Irregular Electrostatic and Magnetic Fields

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Assoc. Professor of Electrical Eng. — Instructor in Electrical Eng.
Both of Marquette University, Milwaukee, Wis.

The safety of electric power cables is dependent in part upon the maximum electrostatic flux density in the dielectric. The core loss in revolving machinery is, in part, a pole face loss, dependent on variations in the magnetic flux density. Alternators work best in parallel, and give less interference with communication circuits, if of a good wave form, of flux density. These fields of electrostatic and magnetic flux are often too irregular to lend themselves to an accurate computation, and hence experimental methods of study are needed. The writers have improved a method suggested by F. W. Carter, and the results obtained give promise of a field for useful study. The method itself may be briefly described as measuring an electric model of the field to be studied cut out of sheet metal. By the use of a contact-making device, with two contacts, held at a fixed distance apart, but movable to any part of the edge of the metal sheet, voltage gradients may be measured upon a galvanometer. From these measurements, the flux densities may be calculated. The paper describes the method in detail and also gives some results of study on the three problems mentioned. It is shown how this method of test can be used to improve pole-shoe design. The importance of pole-shoe design is pointed out. An appendix is included showing that correct pole-shoe design is needed to eliminate the so-called "tooth ripples."

EFFECT OF ALTITUDE ON TEMPERATURE RISE*

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The problem is to determine the effect of altitude in increasing the temperature rise of electrical apparatus.

Stated in detail, heat is dissipated from the various surfaces of apparatus principally by convection and radiation. The former is a function both of temperature rise and of air density, that is, of altitude; the latter, of temperature rise only. The energy loss in the apparatus, that is, the heat to be dissipated, is not changed significantly by altitude. Thus, lower air density at higher altitude means decreased convection. Hence, higher temperature, which increases both convection and radiation, is required to carry off the same heat. Specifically, then, the problem is to relate these several factors so that quantitative calculations can be made for various types of apparatus.

An investigation was made in 1921 to determine how dissipation by convection varies with temperature, air density, and also with respect to the air movement—*i. e.*, whether it is a blast or merely the natural movement created by temperature difference: in other words, whether it is 'forced" or "free" convection. The results check reasonably with those obtained by Montsinger, Rice and others.

The law of radiation, of course, has long since been well known.

The tested apparatus, consisting of electrically heated plates, was enclosed in a large wooden tank or drum, in which the air pressure could be controlled.

The constants from these tests were used in setting up the general equation (**26**), and equations, (**30**) and

*Presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chicago, Ill., June 23-27, 1924.

(**32**), which give the increase in temperature rise occasioned by lower air pressures, for free and forced convection respectively. These are plotted in Figs. 16 and 17. Reasonable assumptions simplify these equations for practical valuations for various kinds of apparatus.

To study altitude effect on actual rotating apparatus, a 7½ kv-a. synchronous motor was tested in the drum at various air pressures. The actual increase in temperature rise agrees well with the values calculated by the above equations. Also tests were made on a 2550-h. p. high-speed synchronous motor, first at Lynn, Mass. (sea level), and later at Cerro De Pasco, South America, at an altitude of 3700 m. These tests afforded an opportunity to check calculations against actual data on rotating apparatus.

Table I gives the increase in temperature rise which, on the above bases, would be expected in various types of electrical apparatus.

THE INERTAIRE TRANSFORMER

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Oxidation is the cause of almost all of the troubles that develop in service in connection with transformer oil and it is thought by the authors of this paper that the obvious remedy for such troubles is to isolate the oil completely from contact with the oxygen of the air. A new method of providing this complete protection in the Inertaire transformer is described.

In this transformer, a body of inert gas—nitrogen—is automatically created and maintained inside the case above the surface of the oil. This nitrogen is obtained from the outside atmosphere by a breathing process in which the breathed air passes into the transformer through chemicals which absorb the 21 parts of oxygen, leaving only the 79 parts of nitrogen to pass into the case.

A second purpose of the nitrogen gas is to eliminate the danger of fire or explosion above the oil surface for no fire or explosion can start or continue without oxygen.

A distinction is made in the paper between a "primary explosion," which term is used to designate a sudden abnormal pressure produced by gas expansion due to arcing in the oil, and a "secondary explosion" by which is meant an abnormal pressure produced by the combustion of an explosive mixture of gases. The hazard of the secondary explosion is eliminated by the absence of oxygen and effective protection against the primary explosion is given by the cushioning effect of the nitrogen body and a new form of diaphragm relief device.

A description of the Inertaire transformer equipment is given, also an account of a number of explosion tests which were made to demonstrate the effectiveness of the gas cushion in reducing the abnormal pressures due to arcing under the oil and of the new diaphragm device in relieving the pressures.

Presented at the Annual Convention of the A. I. E. E., Edgewater Beach, Chicago, Ill., June 23-27, 1924.

LIGHTNING

Does Lightning Oscillate? As a First Approximation, What is the Voltage, Current, Resistance, Energy, Power, Damping, Potential Gradient, and Rate-of-Change of Current?

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By the use of some new experimental data of the resistance of conducting vapors the conclusion is reached that the current in a streak of lightning oscillates. Starting with experimental value of 4500 volts per centimeter, as the average potential gradient for the electrostatic field between the thunder-cloud and earth, some astonishingly high values for the factors involved in lightning resulted. For more than a decade the average current in a lightning stroke of 10,000 amperes has been accepted. The calculations in this paper show a value as great as one-and-a-half-million amperes. Some of the other factors correspondingly large are as follows: The energy stored in the electrostatic field is 700 kilowatt-hours. The maximum power expended in the discharge is 860-billion kilowatts. The frequency for the particular stroke calculated, one mile long, is lower than former estimates,—about 50,000 cycles per second.

Calculations were made of a bolt of lightning which struck a wooden pole protected by a No. 6 wire. The results agree with the independent calculations of the factors given above of a lightning stroke.

In a later paper the subject will be pursued further, and the equation will be recorded.

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Presented at the Pacific Coast Convention of the A. I. E. E., Pasadena, Cal., October 13-17, 1924.

The Lowest Frequency.
Damping of the Oscillations.
Time-Rate-of-Change of Lightning Current Is of the Order of 400-Billion Amperes per Second.
Experimental Confirmation of Rate-of-Change of Lightning Current.
Considerations of the Results.
Summary of the Factors.
Some of the Experimental Facts Used.
Assumptions Involved.

FAIR WEATHER CORONA LOSSES AT 60 CYCLES*
on Large Overhead Power Cables

J. C. Clark and F. F. Evenson
Member, A. I. E. E. — Associate, A. I. E. E.
Assoc. Prof. Elec. Eng. — Benson Lumber Co.
San Diego, Cal. — Stanford Univ.

After defining briefly the problem of the selection of a proper high-voltage transmission conductor, the authors discuss the difficulties that caused the failure of their earlier attempts to measure corona losses at the Stanford University laboratory.

The equipment used for the present investigation, as well as the methods of test and the procedure followed in the reduction of test data, are described. The corona loss is taken as a function of the crest value of the voltage in accord with the theory of Professor Ryan. Insulator losses in fair weather are found negligible.

Errors existed in the authors' measurements of the losses, causing them to be high, but a correction is made by subtracting the "error power" from the gross power curves.

The cable samples are briefly described.

Complete tables of tabulated data are presented in Appendix A; and some idea of the consistency and reliability of the results may be obtained from these tables, and from the various curves.

SELECTIVE CIRCUITS AND STATIC INTERFERENCE†

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The present paper has its inception in the need of a correct understanding of the behavior of selective circuits when subjected to irregular and random interference, and of devising a practically useful figure of merit for comparing circuits designed to reduce the effects of this type of interference. The problem is essentially a statistical one and the results must be expressed in terms of mean values. The mathematical theory is developed from the idea of the spectrum of the interference and the response of the selective circuit is expressed in terms of the mean square current and mean power absorbed. The application of the formulas deduced to the case of static interference is discussed and it is shown that deductions of practical value are possible in spite of meagre information regarding the precise nature and origin of static interference.

The outstanding deductions of practical value may be summarized as follows:

1. Even with absolutely ideal selective circuits, an irreducible minimum of interference will be absorbed, and this minimum increases linearly with the frequency range necessary for signaling.

2. The wave-filter, when properly designed, approximates quite closely to the ideal selective circuit, and little, if any, improvement over its present form may be expected as regards static interference.

3. As regards static or random interference, it is quite useless to employ extremely high selectivity. The gain, as compared with circuits of only moderate selectivity, is very small, and is inevitably accompanied by disadvantages such as sluggishness of response with consequent slowing down of the possible speed of signaling.

4. A formula is developed, which, together with relatively simple experimental data, provides for the accurate determination of the spectrum of static interference.

5. An application of the theory and formulas of the paper to representative circuit arrangements and schemes designed to reduce static interference, shows that they are incapable of reducing, in any substantial degree, the mean interference, as compared with what can be done with simple filters and tuned circuits. The underlying reason lies in the nature of the interference itself.

AUTOMATIC EDISON SUBSTATION
of the Indianapolis Light and Heat Company†

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General Electric Co., Schenectady, N. Y.

This paper describes a two-unit automatic station which supplies power to a 3-wire, 250-volt, d-c. Edison network. It covers a general description of the machines and of some of the devices, of the scheme of automatic operation employed in controlling these machines, and of the method of protecting against emergency conditions.

Although the paper itself deals with this specific installation only, the fundamentals involved are the same for the general class of equipments employed in this service. However, there are generally certain important differences caused by special operating requirements of the individual installation or system. The character of the load determines whether the station is to be in service continuously, or is to be

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placed in service in response to load demand, by remote control or by some other means. The capacity and regulation of the a-c. system determine whether Y-delta, compensator or reactor starting is to be employed. The location of the station with respect to the load and the layout of the d-c. system determine whether only one bus, or both high and low-voltage vuses are required. These and other factors must be taken into consideration so that the equipment will meet the requirements of the individual installation or system.

Hence, each installation is to a certain extent its own problem, for it must maintain the required character of service under all conditions no matter what special operating requirements are present.

THE POSSIBILITY OF FLASH-OVERS

Due to Low High-Frequency Efficiency in the Insulator System Rather than Lack of Unit Factor of Safety or Poor String Gradient

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Much has been written about the electrical characteristics of insulators but comparatively little about the limitations of the air as determining their performance. In this paper the limitations of the insulating systems due to their low efficiency at high frequency is discussed. Attention is called to the necessity of raising the high frequency efficiency in order to eliminate flash-overs, also the advisability of considering string gradient as a means of improving the unit factor of safety rather than as an essential in itself in order that one characteristic in the insulator may not be improved at the expense of another or more important essential.

The possibility of taking advantage of increased flashover voltage due to the use of insulated controls is discussed on the basis of utilizing the difference in time lag to protect connected apparatus which may be subjected to increased voltage.

The practicability of using a few large units in the string to break up drip water or eliminate bird trouble and the advantage of dry units in a wet string are justified on the basis of unit factor of safety.

Two methods of designing are shown for increasing the unit factor of safety to provide for more severe conditions should the present limitations due to the conductor be greatly improved.

Attention is called to the limitations of large smooth conductors for high voltages and the advantages of a conductor having a uniformly distributed roughness.

CONTENTS

1. The satisfactory field record of insulators.
2. The elimination of dead-ends permits the use of low ultimate long life insulators for large conductors and high working tensions.
3. The resilient joint and the resilient pin permit production of high ultimate units with long economic life.
4. Improving the string gradient secondary to improving the air gradient or raising break-down voltage between conductor and ground.
5. Unit factor of safety rather than string gradient measure of insulation.
6. Many flash-overs due to arcing from conductor to ground at comparatively low voltages.
7. The effect of high frequency on flash-over voltage.
8. The insulated control as a means of preventing air break-down and raising the flash-over voltage.
9. Possibility of flash-over at relatively low voltage, due to transients releasing energy stored at normal frequency.
10. Balancing the tested factor of safety on the basis of dielectric time lag.
11. The application of the insulated control to transmission lines.
12. Break-down of air between conductor and ground limiting factor shown by applying insulated control.
13. Air break-down limiting factor for bus structures.
14. Unit factor of safety the real criterion in determining the margin of safety in the insulator.
15. The possibility of increasing the unit factor of safety to take advantage of the much higher voltages due to control of air break-down.
16. The use of sections of large and small diameter in the string to prevent bird trouble and shunting due to excessive drip water.
17. The presence of wet and dry sections in a string analyzed on the basis of unit factor of safety.
18. Balancing the various characteristics to prevent flash-over.
19. Roughness in the conductor or live parts an important factor in determining losses and the elimination of flash-overs.

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DIELECTRIC FIELD IN AN ELECTRIC POWER CABLE-II

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The writer presented a paper in 1919 on the three-conductor cable, giving experimental results for assisting in the calculation of quantities such as capacity, insulation resistance, dielectric loss, temperature rise, etc., and also data on the calculation of stresses at various points in the dielectric. Most of the data were based on cable models composed of metallic electrodes

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surrounded by conducting electrolyte. In the present paper the old data are amplified both in regard to geometric properties and stresses of three-conductor cables, not only in regard to the range of sizes covered, but especially, inasmuch as the present paper includes cables with sector-shaped conductors. The cable models used are entirely different, being in the form of tinfoil sheets. Curves are given by means of which stresses can be calculated in various important parts of the cross-section of three-conductor cables with either round or sector-shaped conductors.

A comparison is made between the results obtained and the results of other observers, and in general the geometric relationships are in very satisfactory agreement. The stress determinations, however, are not in exact accord wih all the work of Emanueli which has appeared since publication of the 1919 paper. Reasons and experimental checks are given indicating why it is believed that the writer's data on stress are correct.

A 35,000-KW. INDUCTION FREQUENCY CONVERTER*

Description, Operating Characteristics and Test Data

O. E. Shirley
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The application of the induction frequency converter is not new, but its use for connecting together very large systems has not been undertaken until the machines described in this paper were put in operation.

This paper describes the rating and mechanical construction of the two units, with special attention to the induction machine.

The testing of the machines was done after installation, and the results of these tests are given.

The theory of the operation of the induction unit is developed, being simplified by neglecting losses and resistance, thus avoiding complicated equations, but securing results agreeing quite closely with the more accurate calculations.

The behavior of the set under short circuits is discussed.

THE QUADRANT ELECTROMETER FOR THE MEASUREMENT OF DIELECTRIC LOSS†

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Both of the Standard Underground Cable Company, Pittsburgh, Pa.

Walker, Skinner, Addenbrooke, Rayner, Orlich, Schultze, Thielers and others have given a great amount of useful information on electrometers for the measurement of dielectric loss. We have found instruments made somewhat after the design of Skinner and Rayner, so rugged and so useful as laboratory instruments, even when the instrument is subjected to severe jars and mechanical vibration, and capable of such great accuracy that we have spent considerable time developing methods of use and investigating the sources of error. Our instruments are essentially high-voltage instruments as the needle may have impressed upon it voltages up to about 8500 volts. One of these instruments has been in use almost continuously since 1913, a period of ten years, and for the last seven years it has been continually in use without needing repairs of any sort, in spite of breakdowns of the load being measured, and no adjustments have been made except an occasional turning of the quadrant leveling screws.

We have developed what we believe to be a new zero method of measuring power factor which has many advantages, and have also used the electrometer as a detector in a high-voltage bridge. We have also gone thoroughly into the errors of the electrometer, both for the deflection and zero methods, and have included these errors in our equations, so that we believe they may be taken care of practically.

Our excuse for publishing this information is that we believe it may be of use to others, and may lead to the more general recognition of the many advantages to be procured in using electrometers.

STANDARDIZATION IN CONSTRUCTION AND OPERATION*

as Applied to Light and Power Companies

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Standardization is a subject that is very much discussed. The advantages of standardization have long been realized by industrial and manufacturing companies. The electric light and power companies seems to be slow in adopting standards of construction and this article relates the experience of one company who tried it out.

ELECTRICITY IN MINES‡

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In the paper, the author has given a complete comprehensive description of the various uses to which electric power is put in and around the mines, together with some interesting figures in regard to the amount of electric power now used and that which is still to be electrified.

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†Presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

‡Presented at the Pacific Coast Convention of the A. I. E. E., Pasadena, Cal., October 13-17, 1924.

THE TRANSIENT VISUALIZER*

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This paper describes a device which is used with the oscillograph for the visual study of transients and for obtaining improved photographic records as illustrated by oscillograms. The principle uses of the transient visualizer are:

(1) To make curves of transient phenomena stationary on the screen of the oscillograph where they may be studied visually.

(2) To start oscillograms of transients at predetermined points on the film.

(3) To leave a blank space on the film for a diagram of connections and essential data.

(4) To make multiple exposures on a film where it is desired to start successive curves from the same point of the film.

(5) To make multiple exposures where each curve occupies but a portion of the length of the film and successive curves start from different points of the film.

(6) To obtain a constant cycle length, independent of frequency variations of the power source, for convenience in comparing curves.

(7) To close the circuit at a predetermined point of the electromotive force wave.

(8) To control the amount and direction of the residual magnetism left in a transformer so the initial magnetic condition will be known the next time the starting transient is repeated, that is, for the next revolution of the drum.

(9) To provide a convenient and accurate means of determining the time calibration.

(10) To make possible progressive studies where circuit conditions are modified for successive exposures and brought together for convenient comparison.

STREET LIGHTING—A MUNICIPAL† PROBLEM

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Consulting Engineer of the City of Syracuse, N. Y.

A large proportion of the recent contributions to the engineering literature on street lighting has been from the viewpoint of engineers interested in the sale of electricity or equipment. In this paper the problem is approached by a representative of the municipality.

While recognizing the importance of fairness to the seller, it has been the duty of the author to see that the buyer's money was economically spent and that the best practicable lighting was furnished to the public in the interest of safety and the progress of the city. Many city governments already realize that money spent for street lighting reduces the amount necessary to be spent for other safety measures.

In 1922, the City of Syracuse, after an extensive study and with the advice of a prominent consulting engineer, decided to institute a program for improving the street lighting along certain general lines. Shortly after the beginning of this study, the author was employed by the Bureau of Gas & Electricity of the Department of Public Safety in the capacity of Consulting Engineer in charge of all street lighting, besides other electrical engineering work. The determination of type, spacing, and other considerations come under his direction.

In the belief that these problems are more or less typical of those confronting other cities and that there is a real need of greater engineering attention to street lighting questions on the part of many cities, it seems well worth while to discuss what has been learned along these lines.

Furthermore, as Chairman of the Joint Street Lighting Committee appointed by the Conference of Mayors of New York State and the Empire State Gas & Electric Association, access has been had to a considerable amount of survey data and the opportunity of broadening of viewpoint has been presented.

The conclusions reached after connection with these two studies conducted under such favorable auspices and with such cooperative activity should be of value to all those responsible for the engineering of street lighting.

The first part of this paper is devoted to the conclusions reached in connection with the lighting of streets in the City of Syracuse and the second part to the more general considerations of the Joint Committee.

OPERATING EXPERIENCE WITH AUTOMATIC EQUIPMENT* on an Edison System

F. D. Wyatt
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The paper describes the conversion equipment serving the Edison System in Cincinnati and the application of automatic machines and controls to that system. During two years' operating experience with automatic equipment, it was found to be very reliable and to operate much quicker than manually-controlled equipment. Tests on the automatic equipment show it to be very valuable for service restoration work.

ELECTROMETALLURGICAL APPLICATIONS†

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General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

This paper deals with a field of engineering in which electrical, chemical and metallurgical engineers are

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all interested, and have responsibilities. It contains a discussion of electrical power utilization developments which are based upon fundamental principles of physical chemistry and electro-chemistry. It outlines the particular functions of the electrical engineer and indicates his close co-relationship with the chemist and metallurgist in the solution of such industrial problems. It deals only with metals which are ordinarily employed in construction or manufacture and in the production of which large quantities of electrical power are employed. Smelting and electrolytic methods are compared; data and illustrations on plants and equipment for the production of iron, zinc, copper, nickel, aluminum, etc., are included.

TESTS ON 22-KV. AND 4-KV. LIGHTNING ARRESTERS*

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The development within recent years of high-voltage rectifying tubes has made possible the construction of an apparatus which may be used to produce very high-voltage surges of steep wave front, believed to be comparable in potential and capacity to surges caused by lightning discharges taking place near transmission lines. With such an apparatus it has become possible to conduct tests on lightning arresters which show clearly the kind of performance these arresters are giving in service.

The Duquesne Light Company has had on its system a great number of lightning arresters of the horn gap and series resistance type. The number of failures on installations these arresters were intended to protect and the number of failures on the arresters themselves have led the engineers of this company to go rather deeply into the lightning-arrester question and into the problem of determining, before an arrester is installed, just what degree of protection it is likely to afford.

To get the information desired it was found necessary to make a series of tests on the various arresters now in the market. In making these tests, arbitrary requirements were set up as being necessary in an arrester for satisfactory operation on this system. These requirements were as follows:

1—High speed of discharge
2—Ability to break down dynamic current
3—Ability to operate repeatedly

The protective value of arresters meeting these requirements was felt to be proportional to the discharge capacities of the arresters.

This paper sets forth the results of the tests made on 22-kv. and 4 kv. lightning arresters.

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ACCEPTANCE TESTS FOR HYDROELECTRIC PLANTS*

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This paper discusses acceptance tests of hydroelectric plants and explains the various methods of testing hydraulic turbines. Various units which compose this equipment are described and the author shows how to apply the data obtained in the most economical and efficient way. The article contains a number of illustrations to emphasize and make clearer the analysis, which he sums up in the theorem: "The load should be divided between two or more units so as to obtain equal values of the first derivatives of the power discharge-curve of each unit." A table, showing the correct division of load, is given, which operators would find helpful.

RECEIVING BROADCASTING OF HIGHER FREQUENCY

Some broadcast receiving sets now in use cannot be tuned conveniently to stations broadcasting on frequencies higher than 1000 or 1200, *i. e.*, not below 300 or 250 m. The Third National Radio Conference recommended that the broadcast band of frequencies be extended to 1500 kilocycles (200 m). This emphasizes the importance of the production of sets which will tune conveniently at the higher frequencies, and the desirability of information on how to use existing sets so that all stations may be tuned in. The range of receiving sets which employ a single tuned circuit, (*i. e.*, where the antenna is part of the tuned circuit) may be extended to the higher frequencies without much difficulty. This applies both to crystal and tube sets. It can be done very simply by providing a fixed condenser (about 0.0002 microfarad) in series with the antenna which may be switched in or out of the circuit. The settings of the dials are different when the condenser is in and out of circuit. Shortening of the antenna likewise reduces the capacitance and consequently increases the maximum frequency (minimum wave length) to which the set will tune.

In the two-circuit and other more complicated receiving sets the extension of the frequency range may not be so convenient. A general rule, however, may prove useful. The natural frequency of a circuit is determined by the product of the inductance and capacitance in the circuit; the larger this product the lower the frequency (higher the wave length). To increase the frequency to which a circuit will tune, it is only necessary to decrease either the inductance or capacitance, or both. The inductance may be reduced by reducing the number of turns, while a reduction in the number of plates or increase in spacing of the plates reduces the capacitance of a condenser. The effective capacitance in a circuit may also be reduced by using two condensers in series. Changes in receiving sets of this type can, in general, be readily made by radio listeners who construct their own sets.

Interconnection of Power Systems in the Southeastern States

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SUPERPOWER, or giant power, as Governor Pinchot prefers to call it, has been very much before the public for the last two years. General Tripp with his clear vision and masterly exposition of this great subject has done much to clarify and make understandable to the general public the problem involved and the effect of its solution. The appeal to the imagination of a completely electrified country has resulted in great public interest in the matter, so that it is but natural for the politicians seeking an issue and the advocates of government ownership to give their attention to this new problem as being fraught with more possibilities than the more settled railroad, telephone and telegraph systems. While there is a tremendous engineering problem involved, there are other and equally important phases that must be carefully considered before superpower and complete interconnection will be an accomplished fact.

Our great problem for the next ten years is to increase the capacity of these interconnections, to develop the distant waterpowers, the mine mouth, or other strategically located (from an economic standpoint) high-capacity steam plants and connect them with the great load centers by means of superpower networks at 154,000 volts or higher. While the problems of interconnection, power interchange and the operation of interconnected systems differ in detail in different parts of the United States, there are certain elements in common. For this reason a review of what has been and is being done in the Southeastern States may be of interest to members of the Institute.

The territory embraces Mississippi, Alabama, Tennessee, Georgia, North and South Carolina. The principal power companies in this territory are Southern Power Company, Carolina Power & Light Company, Georgia Railway & Power Company, Central Georgia Power Company, Columbus Electric & Power Company, Alabama Power Company, Birmingham Electric Company, Tennessee Electric Power Company and the Memphis Light & Power Company. The paper contains a map showing the territory and the principal transmission systems.

The drainage area is that of the southern extremity of the Appalachian Mountains. The flow characteristics of our rivers are very different from those of the far West or the North. We do not have the melting snows of high mountains to give us the maximum stream flow during the summer and fall seasons when our ice, cotton gin and cotton seed oil mill loads are heaviest. W. S. Lee, a distinguished member of our Institute, has well called them "the fugitive waters of our Southern streams." Variations of 1000 to 1 between maximum and minimum are common, and the wide variations in stream flow necessitates large steam reserves or storage reservoirs.

The topography of the country is such that the majority of power developments utilize heads of from 50 ft. to 150 ft. The exceptions are the plants of the Georgia Railway & Power Company on the headwaters of the Tallulah River, where a maximum head of 608 ft. is developed in one plant and the plants of the upper Ocoee River of the Tennessee Electric Power Company where heads of 250 ft. are developed.

There are no coal deposits in Georgia or the Carolinas or Mississippi. Freight rates from the Alabama, Tennessee, Kentucky or West Virginia fields to Georgia or the Carolinas are high. Therefore, the great steam reserve plants of the future for this district will be located in Alabama or Tennessee, with the probability of the connection of the North Carolina systems with mine mouth steam plants in West Virginia. The Southern Power Company in its Bridgewater plant has developed a water storage equivalent to 110,000,000 kw-hr. of energy. The Georgia Railway & Power Company, in its Burton and Mathis Dams has developed approximately 90,000,000 kw-hr. of storage. Alabama Power Company, in its Cherokee Bluffs project, now building, will have an available storage of 300,000,000 kw-hr.

Hydroelectric development in the South on a large scale was started by James Duke and W. S. Lee of the Southern Power Company about 20 years ago. The system serving this territory has now one of the greatest transmission networks in the country and its peak load is in excess of 275,000 kw. It was followed by the Yadkin River Power Company in North Carolina, the Georgia Railway & Power Company on the Tallulah, The Tennessee Electric Power Company on the Ocoee, the Columbus Electric & Power Company on the Chattahoochee, and the Central Georgia Power Company on the Ocmulgee River. Development in Alabama did not start until 1912 when construction of the Lock 12 Plant on the Coosa River was commenced. The load has been developed very rapidly by the Alabama Power Company and today it ranks second to the Southern Power Company in output.

The first interconnection between large systems in the South was made in 1912 near Atlanta between the

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Georgia Railway & Power Company and the Central Georgia Power Company. In 1914 the Georgia Railway & Power Company connected with the Columbus Electric & Power Company at Newnan, Georgia, and about this same time with the Tennessee Electric Power Company near Rome, Georgia, and with the Southern Power Company at their Tallulah Plant. In 1921 Georgia Railway & Power Company and Alabama Power Company joined their systems at the state line by a 110,000-volt line from Gadsden, Alabama, to Lindale, Georgia. This year a 110,000-volt line was completed between North Auburn, Alabama, on the Alabama Power Company's system and West Point, Georgia, on the Columbus Electric & Power Company's system. The Georgia Railway and Power Company is now completing a new 110,000-volt line between Lindale, Georgia, on its system, and the Ridgedale substation at Chattanooga on the Tennessee Electric Power Company's system. There is under consideration a line at 110,000 volts between Huntsville, Alabama, on the Alabama Power Company's system and Hales Bar, Tennessee, on the Tennessee Electric Power Company's system. We have a complete interconnected network embracing ten companies and extending over five states. An important feature is that the interconnections have what until recently would have been considered high interchange capacity, that is, of the order of 20,000 kilowatts to 25,000 kilowatts.

The fall line marking where the rivers of the Central States and of Tennessee and Alabama break through to the coastal plain swings down from Keokuk on the Mississippi to Muscle Shoals, Alabama, on the Tennessee, to Lock 18 a few miles above Montgomery on the Coosa, to Tallassee on the Tallapoosa River and to Columbus on the Chattahoochee River. There is no water power of any magnitude south of these points to the Gulf of Mexico. If, therefore, Mississippi and Louisiana are to have the benefit of widely distributed hydroelectric power, it must come from Alabama. It is logical to anticipate, therefore, that within the next five or ten years power from Muscle Shoals and other Alabama hydroelectric plants will be transmitted to Memphis, Tennessee, across Mississippi and even to New Orleans, Louisiana, a distance of approximately 300 miles. When this is done, seven states with a population in excess of 16,000,000 people will be served from what, due to interconnection, will be virtually one great system.

Prior to 1920 the lack of any federal water power laws hindered hydro development on so-called navigable streams and forced the building by the Alabama Power Company, in 1916, of the Gorgas Steam Plant about 35 miles from Birmingham, Alabama, in order to take care of the rapidly growing load which exceeded the low water capacity of Lock 12. The Gorgas plant is exceptionally located from the economic standpoint, situated as it is on the shore of Lake Bankhead, formed by the government navigation dam at Lock 17 on the Warrior River, and in the center of a large coal field with good steam coal mined within 1000 ft. of the plant.

The entrance of the United States into the World War and the War Department's decision to build a great nitrate plant at Muscle Shoals led to a 30,000-kw. extension of the Gorgas Steam Plant, the construction at Muscle Shoals of a 60,000-kw. steam plant in 1919 and the start of construction on the Muscle Shoals Dam No. 2 or Wilson Dam, all of which have been more or less in the public eye for the past two years.

The World War emphasized the necessity of co-ordination of resources. In 1918 a survey was made by the War Industries Board, under the direction of Frederick Darlington, of the available power in these states and of how the power resources should be developed and co-ordinated to give the greatest service. This report recommended large capacity tie lines between companies and showed clearly that the most economical use could be made of the power to be generated at Muscle Shoals by operating it in connection with the plants of the existing companies.

Following the close of the war, there continued to be a serious power shortage, particularly during dry seasons. This led to the construction of a line between Gadsden, Alabama, and Lindale, Georgia. This was very advantageous, because it permitted the Alabama Power Company's mine mouth steam plant to operate at 100 per cent load factor, 24 hours a day, the surplus power above that required in Alabama going into the Georgia Company's system where it could be absorbed even at night, as this company had ample storage capacity and so could completely shut down its hydroelectric plants after the peak load hour in the evening.

In 1922 the power shortage in Georgia and the Carolinas was even more acute than during the previous two years. The situation was brought to the attention of the Secretary of War with the request that the Power Companies be permitted to temporarily lease the 60,000-kw. Muscle Shoals Steam Plant, which was then idle. Following an investigation by army officers, the Secretary of War leased the plant and the Alabama Power Company has since operated it for the companies interested.

Interchange between the Southeastern power companies proved so successful that 18 months ago executives of the various power companies decided that still closer co-operation would be beneficial. An operating sub-committee was formed with one representative from each company's operating department. This committee meets once a month, exchanges information in regard to load and rainfall conditions, energy generated on each system by hydro and steam, and discusses such matters as voltage regulation, load dispatching and system protection. The work of this committee has proved of very definite benefit. Its successful work has caused the executives to go a step further and an engineering sub-committee has now been formed, consisting of the chief engineer or executive engineer

of each company and studies are being made of the possibilities of a co-ordinated development program, with the object of avoiding construction of two or more large plants by different companies at the same time, if one development plus interchange will handle the load. In this manner one company might save the fixed charges on a very large investment for two or three years while the other company would load its new development from the date of completion with not greatly increased operating costs. Under such circumstances it ought to be possible to work out a mutually advantageous interchange.

An interchange contract must be made before tie lines can be built and power interchange actually takes place. Upon the type of agreement between the interconnected companies is largely dependent the success of the project and its most economic use. Quite naturally, the first tie lines were built to enable a company having a surplus of energy to sell it to another company which was short of power. Following this came agreements covering emergency service, and later, agreements for straight interchange. All these different conditions must be covered by contract, and rates established. Furthermore, rates must be varied, dependent on whether surplus or dump power, steam power, with a clause varying the rate as the price of coal varies from the base price, or hydro storage power is being supplied. It is readily seen, therefore, that the drawing of a contract is not simple. Fortunately, after the contract is drawn with all its legal phraseology carefully protecting every right of both parties and arranging at great length for the arbitration of disputed points, it is usually forgotten, except the rate clause, and operation under it is decidedly simple. O. N. Hollis, of the Detroit Edison Company has just delivered a most excellent paper before the Association of Edison Illuminating Companies, on the subject of interconnection rates and contracts which brings out in detail many of these points. In the Southeast all these forms of contract are in use.

Many interesting features occur in the operation of interconnected systems. For example, the tie line between Gadsden and Lindale is a single-circuit wood pole *H* frame line of 3/0 steel core aluminum 53 miles long with a nominal rating of 20,000 kw., yet at times 35,000-kw. load has been successfully carried over the line.

Of course, in transmitting power in blocks of 15,000 to 25,000 kw. over these tie lines, power-factor correction is absolutely essential. It is desirable to operate these lines at as near unity power factor as possible. Synchronous condensers are being installed on the various systems for power factor correction. During the year 1923 the Alabama Power Company installed on its system approximately 20,500-kv-a. in synchronous condenser capacity and during 1924, an additional 27,500 kv-a. will be installed. These condensers, of course, are located near the load centers to secure the maximum possible benefit of power factor correction. The Alabama Power Company is now installing a 25,000 kv-a. turbo generator at its Gorgas steam plant and provisions are being made for disconnecting the generator from turbine and operating the generator as a synchronous condenser. This is especially desirable since in the wet season the steam plants are shut down and as the hydro-plants are located in the opposite section of the system, operation of the generator as a condenser materially improves conditions throughout the system. During the dry season hydro generators are floated for power-factor correction. By shutting the wicket gates and breaking the vacuum in the draft tube on the machines, it is possible to operate generators for power-factor correction with only a small loss of water. This same practise is, of course, followed by other companies on the interconnected network and the system supplying energy is relieved, insofar as possible, of excess reactive component by systems receiving the energy, these systems using their spare generator capacity for power-factor correction. Although without doubt the proper place for the major part of power-factor correction is at the customers' load, a certain amount of correction is necessary in large load centers where large capacity condensers can be installed and definite control of voltage conditions can be secured.

High-voltage metering equipment is necessary for the interconnecting lines and it has been the practise to install this equipment in substations to which the lines connect. Comparatively little trouble has been experienced in the high-voltage metering equipment.

In general, 110,000-volt oil circuit breakers are used for synchronizing purposes. Inherently, these breakers are slower than the low-voltage breakers in generating stations. However, with a little practise the operators are able to synchronize systems with no adverse effect to either of the systems. To successfully operate the transmission systems in parallel and at the same time secure the proper load adjustments between the various generating stations and between the systems themselves, it is essential that the frequency be rigidly maintained at 60 cycles. Some difference was always found in the frequency indicators in spite of careful calibration, but this difficulty has been overcome by the installation of Warren Master Clocks at either the principal regulating stations or at the load dispatchers' offices. The Master Clock makes it possible to maintain an average frequency within very close limits.

It has been found that the regulation of frequency must be controlled by the base load stations and especially the base load station of the system supplying the bulk of the power, all other stations making the necessary governor adjustments to fall in step. The governors at all stations taking the load fluctuations should be equally sensitive so that all systems can properly carry their share of the fluctuations.

Operation is handled between load dispatchers on

the various systems. It has been found advisable to establish a central load dispatching point at Atlanta and all messages concerning the dispatching are usually relayed through Atlanta to the interested systems. Where a company desires to purchase energy the Operating Superintendent or Engineer customarily advises the Central Load Dispatcher of the amount of power desired on interchange and this is relayed to the dispatchers of the proper systems. In case of emergency, the Load Dispatchers have authority to act and it has frequently been possible to save very important loads by quickly bringing in additional generating capacity. In this way interruptions due to line trouble are reduced in number and duration.

Effective relay protection is essential for the successful operation of the interconnected systems and each company has made many improvements in protective layouts during recent years. It is desirable to immediately relieve the system of short circuits by tripping out the faulty line or equipment as quickly as possible. Differential protection for transformers and generators and, insofar as possible, balanced protection for transmission lines have been applied.

The problem of voltage control is very important since it affects the distribution of reactive current between the various systems, the systems maintaining the highest voltage taking more of the reactive component. If the system supplying energy also supplies the reactive component associated with it, then the voltage drop over the tie line will vary according to the load on the line; *i. e.*, from zero at no load to a maximum at full load. Where the range of load is great, too wide a range of voltage is required for satisfactory service. It is possible, however, to maintain constant voltages at both ends of the tie line over the entire range by varying the magnitude of the reactive component transmitted. This method has the disadvantage of increased losses due to the flow of large reactive currents at light loads over the tie line. The best method, perhaps, is to strike a compromise and allow the voltage drop over the tie line to vary within permissible limits, allowing reactive currents to flow to maintain these limits. With a heavy load on the tie line this may mean that the receiving system must supply all of the reactive current of the load received and in addition, same reactive current to the line so that the load can be transmitted at a leading power factor.

All engineering studies have been made on a weekly basis, both as to available water and to power consumption. Yearly flow curves are plotted, using the 52 weekly flow points instead of 365 daily flow points. While studies have been made of the wettest and driest years, a careful analysis indicates that studies of plant capacities and generation, based on what we have called a median year, give best results. A median year flow is a theoretical year built up by using for each of the 52 calendar weekly flow points that week which has the same number of years showing this same calendar week with a greater flow as there are years showing it with a lesser flow in the total number of years for which the data are available. There is no such thing as an average year and in our efforts to get a safe typical year and not have to make a study of all load conditions for all the years for which data are available, we have arrived at the median year as here defined which seems to be safe and to materially lessen computations. Typical weekly load curves are shown herewith.

There is necessarily a great deal of tiresome computation in hydraulic studies covering periods of years. To lessen it, C. James, Assistant Chief Engineer of the Alabama Power Company, has developed a very interesting curve showing distribution of load between different plants, which has proven exceedingly convenient and accurate. While many other forms of curves are used, the one we use lends itself readily to a determination of the position of a given plant in the load curve.

The usual weekly load curve, as plotted by the Alabama Power Company, shows the kilowatt hours generated for each hour of the week consecutively, from Monday to the following Sunday, inclusive. In the power studies it is often important to know the kilowatt hours which a certain plant can generate, knowing its kilowatt capacity and position in the load curve and the stream flow. This is an area on the load curve as plotted and considerable time would be necessary to determine it in each of the many cases when it is needed. The distribution curves above referred to are in the terms of kilowatts and kilowatt-hours, so that for any known kilowatt demand and position on the load curve, the kilowatt-hours can be read on the curve, or vice-versa.

In conclusion, it may be said that the various power companies are fully aware of the benefits of interconnection and are intelligently planning to take the maximum advantage of it in the future. Executives, engineers and operating men are working in the closest cooperation. To meet the needs of the rapidly growing industrial load of the southeastern states will tax the ability of the public utilities in this district. Tie lines much larger than the present must be constructed, and their design is a serious engineering problem, when proper consideration is given to protection of service, and to voltage and power-factor control. It may well be that a high-tension network of the type proposed by Percy Thomas in his paper before the Institute last April is the ultimate solution. That the problem is worthy of the best technical study is evident when the present capacity of the interconnected systems is considered.

Installed Hydroelectric Generating Capacity....................	782,000 kw.
Installed Steam Generating Capacity..........................	353,000 kw.
Hydro Storage Capacity..........	225,000,000 kw-hr.
System Output in 1923...........	3,250,000,000 kw-hr.
System Peak.....................	740,000 kw.

and the further fact borne in mind that, according to the best data available, these figures will be doubled in 1930.

The Place of Standardization in Modern Life

BY A. W. WHITNEY

Chairman, American Engineering Standards Committee

I am unusually glad of the opportunity to speak to you tonight, for it seems to me particularly important at this time that a statement should be made about some of the more fundamental aspects of standardization, and I am fortunate in having the chance to discuss this subject before a body which has not only done such high-grade work in this field, but whose members are so well able to get to the heart of any subject that comes before them.

We have in our keeping a powerful instrument. Like any other powerful instrument it can be used for both good and evil. We have an obligation both to those we immediately represent and to society to use standardization not only so as to avoid doing harm but so as to accomplish the greatest amount of good.

It is not uncommon now-a-days to see articles and editorials and letters in the public press deploring the state of uniform mediocrity that standardization will produce if allowed to have its way; this may even be considered to be a standard objection to standardization; in fact with fine irony a syndicated editorial on the evils of standardization has recently appeared in papers throughout the country.

That the question is receiving public attention indicates two things, first, that standardization is now generally recognized to be a matter of importance and, second, that either a real danger exists or else a popular misapprehension of what standardization aims to accomplish. In any case, the situation calls for light and discussion.

May I take advantage of this occasion to make a general statement to the effect that business and industry must increasingly feel an obligation to discover the social implications in what they are doing. It is not enough to justify an institution merely by its effect upon business, for business, the supplying of the material needs of the world, must look for its own justification to its effect upon society. The place of standardization must therefore be judged from this broader, more thoroughly human point of view.

The questions that must be considered are these: is standardization a desirable and necessary process; if so, what is its exact place in the world; and second, how is it susceptible of abuse and how can such abuse be avoided? In order to answer the first and main question, it will be enlightening to realize the part that standardization has played in nature.

The processes of nature and of man are after all very much alike. The designing-room of nature is continually turning out new ideas in plant and animal life. These she tries out not on a special testing floor but in life itself. If they are worthwhile, the new forms find a place for themselves and live; if they are badly designed they die and leave no descendents and the model is discontinued.

The advance that man has made, building upon all that nature can give, lies in the ability to experiment. He does not have to wait for the slow process of mutation and for an actual trial in life itself. Thought consists essentially in the ability to try the world out in imagination. The architect's plan for a house is essentially his way of being able to live in imagination in the house and if in this imaginary life he finds that there are no stairs to the attic and that he has an inconvenient time getting a bath, it is not necessary to tear the house to pieces in order to make the correction but only to do some more thinking. All thought, even the most abstract, is essentially a way of imagining life.

There should be then a strong resemblance between the processes of nature and the processes of man, the difference being that nature works through the infinitely slow method of trial and error and deals with life itself, while man works largely in a thought-world and in the laboratory which, while one stage nearer, is still far short of being actual life. All this being so, the part that standardization has played in nature should give us a very excellent idea of the part that standardization can play and should play in the world of human activity.

Nature, by some innate property of germ-plasm, stimulated apparently by the varying conditions of the environment, is perpetually creating new variations in plant and animal life. This is precisely analogous to the creative faculty in human thought. This process of nature, uncontrolled, would fill the world with endless variety. There would not only be the myriad types that we now have but innumerable modifications of these types. Natural selection however, acting upon this variety, has had the effect not only of choosing certain types as worthy to survive, but of endowing these types with a certain degree of permanence and stability and isolation. It is as though nature had not only given each type a chance to survive but had gone further and cleared out the weeds nearby so as to give it the best possible opportunity to get light and air.

The effect is that nature, instead of filling the world with a continuum of plants and animals, has filled it with a discrete and actually enumerable assemblage of types, and furthermore, an ordered assemblage, each of which has a considerable degree of stability and among which certain type-conserving forces operate, such as those that inhibit miscegenation.

Address delivered before the A. I. E. E. Annual Convention, Edgewater Beach, Chicago, Ill., June 25, 1924.

Now this establishment of a system of discrete and enumerable types in nature is the exact analogue of standardization as a purposeful, human activity, and the two are subject to the same laws and to the same abuses.

Not only has nature developed types which can be enumerated and classified but she has standardized for each a multitude of organs and functions. Individuals of the same species resemble each other in the minutest details of structure and function. If this were not so, organized life would be practically impossible. Everything would be an individual problem with no possibility of generalization. We scarcely realize how completely our civilization depends upon this. Institutions and customs would be impossible for institutions and customs and laws depend upon an underlying sameness of reaction. There could be no medicine for there would be no uniformity of physical organization or response; there could be no surgery for the surgeon would not know whether he were cutting into a heart or a liver; there could be no organized education because each mind would be an educational problem by itself. An underlying sameness is the basis for every civilization.

I do not overlook the fact that with this sameness goes along a strong flavor of variety and individuality. No two faces are exactly alike and no two temperaments and personalities are exactly alike but this very difference, which undoubtedly gives not only much of the charm to life but which is as well the cutting edge of progress, can flourish only on a deep-lying basis of uniformity. It is the differences that persist, some of them racial but many of them cutting across racial lines, and that account for the actual diversity of civilizations and institutions. Thanks be for the diversity but, still more deeply, thanks be for the sameness that makes the diversity possible and effective!

There are then in nature these two fundamentally different tendencies; first, a force that is continually operating to produce greater variety, and, second, a force that is continually operating to eliminate unsuccessful variations and to concentrate upon relatively few types which in their main features are reproduced faithfully from generation to generation.

Now both of these processes are absolutely necessary in a world of progress and each depends intimately upon the other. Variation is creative, it pioneers the advance; standardization is conservational, it seizes the advance and establishes it as an actual concrete fact. Variation is primarily concerned with quality, standardization is primarily concerned with quantity, that is, with mass-production. If the world were broken up into an innumerable number of forms with no rallying points at which nature had carried on mass-production, there would be no way of expressing the fact that the successful type had been discovered. In order to make progress, not only must there be a better type but it must be made the prevailing type. If nature had no mechanism for fixing and holding the type, she would have no way of capitalizing her discoveries. Furthermore, there would be no adequate basis from which to spring in order to make the next advance. Variation is the active, creative, masculine force in evolution; standardization is the passive, brooding, conservational, feminine force out of which comes the potency of the next advance.

When we come to the directed, purposeful evolution of human society, the main lines are the same. Creation is here essentially variation from normal. Poincaré has even ventured the thought that creation, carried on as it is largely in the subconscious, may be fundamentally fortuitous, the most actively creative mind being that one which is able most quickly and most surely to run through all possible combinations of the elements of the problem and to appropriate those that have value. It is as though the mind were a shaker of dice, the most creative mind being the one that shakes the dice most eagerly and that is most clever in recognizing the winning combination. Standardization is here as in nature the selective and conservational force, the selection being made consciously, however, instead of through trial and error, although even in human standardization actual experiment has a large part to play.

When the type has been thus selected, economic laws fortify the selection by directing the forces of mass-production upon it and it assumes a place much analogous to that of a species in the world of nature. So just as in nature standardization operates to capitalize the advance by making it an actually prevailing type.

It is this effect that is commonly in mind when the attempt is made to evaluate the place of standardization in civilization. It is measured in terms of its effect upon mass-production, it is evaluated as an instrument for making the advantages of life more abundantly available; and the critics of standardization also attack it at exactly this point, on the ground that its effect is coarsening since its results are to be measured in terms of quantity rather than quality. They conceive of standardization as producing a world of universal, dull mediocrity, in place of the world of color and scintillating lights and shadows and heights and depths that we have under the play of individual initiative.

While such adverse effects when produced will be largely due to the unwise use of standardization, it is also quite necessary and pertinent to say that such criticisms completely overlook another and equally important effect of standardization that is quite wholly on the other side of the balance. I refer to the effect of standardization as liberator rather than conservator.

Suppose the world of living nature really had the properties of a continuum; it would be a world of complete individualism; there would be no foci about which to group mass-action, about which to gather the integrating and ameliorating forces of affection and loyalty. It would be a mad, restless, wearying world of infinite

but meaningless variety and detail, obeying no laws except the laws of probability to which even the molecules in their aimless wanderings give allegiance.

Creative work in such a world as this would be an impossibility. Nothing would stay put; there would be nothing to stand on to make a fresh advance. All one's energies would be used up in meeting the idiosyncrasies of the immediate moment. In the field of industry each piece of machinery would be an individual problem, even each screw, each bolt and each nut. What time would be left over amid such maddening detail for fresh advances?

Standardization is thus the liberator that relegates the problems that have been already solved to their proper place, namely, to the field of routine, and leaves the creative faculties free for the problems that are still unsolved. Standardization from this point of view is an indispensable ally of the creative genius.

Nature has very well understood the necessities of the situation. She has not only provided the brain with which to solve new problems but she has provided the reflex nervous centers to which to relegate the control of habits, which are only the clerical assistants of thoughts, so that the brain may be set free for a more primitive contact with reality. Standardization is similarly the habit-forming process in industry.

I have referred specifically to the standardization that has to do with types of plants and animals and also to the industrial standardization that we are familiar with, but in passing, I should call attention to the fact that standardization has a still wider scope. In a very real sense all the conservational forces of civilization are within the field of standardization: institutions, customs, morals, laws, literature, art, science, all involve the registration and relative fixations of advances that have been made into a better understanding of the world, and they are all of them in turn points from which to make fresh advances.

So far, I have been concerned solely with what might be called the hygiene of standardization, that is, with evaluating the place that it should play in the world under normal conditions. This is a far easier task than to treat the pathology of standardization, that is, how it may be abused in a world that is itself more or less out of joint. One may get along with generalities when it comes to describing the ideal, but when one is diagnosing disease he must be specific and put his finger upon the exact trouble.

Standardization undoubtedly has its diseases; it would be strange if it did not. It is curious that nature itself has misused it. Nature having discovered the type proceeds to produce replicas in incredible numbers; the way in which babies, guinea-pigs, grasshoppers and dandelions appear in the world beats any feat of industrial mass-production. And often such production is quite unsuited to actual conditions or is productive of positive harm, as when a small apple tree produces so many apples that not only are they of inferior quality but they are produced at a sacrifice of the vitality of the tree.

Standardization itself is so thoroughly fundamental and necessary a process in both nature and civilization that any evil effects must be looked for not in the process itself, but in the way that it has been applied. It is probable that all abuse of standardization comes from directing it toward too limited an objective. It is either used to accomplish some immediate purpose, overlooking the larger and fuller good that might be accomplished if a longer view into the future were taken, or it is used to meet the needs not of the public as a whole, but of some particular interest. Nature, when she let the apple tree overload itself, allowed herself to be unduly concerned with the danger of the world's running out of apple trees in the next generation, overlooking not only the need of keeping the trees she already had, but the need of good apples for the present generation. She erred in this particular case by being too far-sighted. We commonly err on the other side by aiming at an increase in our immediate material production, when this can be had only by the sacrifice of greater ultimate values.

The further we progress on the road of industrial standardization, from standardization by the individual worker to standardization by the factory, from standardization by the factory to standardization by the industry, from standardization by the industry to standardization for all industries on a national basis, the more clear does it become that standardization must be a process by which a consensus of all interests is reached in a thoroughly representative and democratic manner. Nothing else has permanent value; but when standards are prepared in this way we are made to know that we are on the right road by what has always been the sign to those that have kept the faith, a miracle.

When diverse elements are brought together, the result may be a compromise; it often is a compromise, particularly if the result is reached through the efforts of those who do not understand and who make no effort to understand; but when a body of sincere, well-meaning, understanding persons comes together in the continuing presence of the truth, however diverse their interests may apparently be, a marvellous thing happens, a solution appears which is not a compromise but which in the majority of cases is the best for all concerned.

Standardization is a religion and the faith of this religion is the belief that a way, perhaps the best way, can be found at each point along which the progress of the world should take place.

There can be little to fear from standards that have this quality. I can scarecely believe that movements of the trained athlete, the swimmer, the oarsman, the tennis player, which are primarily chosen to produce the most effective results with the least effort, are not performed with a grace and ease that brings enhanced satisfaction to both the athlete and the spectator. I

can scarcely believe that motion that will produce the greatest physical results with the least fatigue will not be correlated with both bodily and emotional satisfaction to the worker.

The sine curve and the catenary which are the very symbols of physical rightness in a multitude of fields are also lines of the most subtle beauty. The hawk when he descends in the form of a cycloid most quickly to reach his quarry is also executing a movement of perfect grace.

It is not the real standards that we need be afraid of. If they are right, they will find a place for themselves in civilization and will only go toward building up that great, wholesome, restful sameness which is the real basis not only for a democracy, but for an aristocracy, and the only basis on which new growth can take place. It is the standards that do not represent a real consensus of all those interests that are concerned in progress which we should fear.

The safeguards against bringing such ill-begotten standardization into the world can only be a realization of the high and serious mission of the standardizer, and an almost religious consecration to the duty and privilege of helping to direct progress in this fundamental way.

This has not been the paper that you have expected, nor has it been just the paper that I had expected to give you. There are a world of practical questions that might be discussed that have a bearing on how we can perform our work so as to avoid those errors which our critics fear and others which they are not clever enough to realize: How early in the development of an art should standardization begin? what fields should be avoided? How far should standardization and simplification go? What can be done to make standardization a process not of permanent, but of only relative fixation, not impeding progress but changing with progress, and, most important of all, how can we most effectively bring to bear upon the problems of standardization such a broad vision that we shall make it a real instrument of progress itself.

These are the practical problems. I saw, however, that it was impossible to discuss both the philosophy of the thing and the practical problems in one paper, and so I chose the former because it seemed to be the more necessary and fundamental undertaking, but also, I fear, because it was the easier.

In closing, may I make an application of this general reasoning which will have the advantage not only of being concrete but of bearing directly upon our modern life.

The development of the common law is a remarkable example of the working of standardization. In fact, it is perhaps that institution of civilization which has developed most nearly by a natural process. The common law is the result of the gradual growth of a consensus of opinion as to what conduct will on the whole produce the best possible society. It is a slowly acquired body of standardized rules of conduct. It is not the work of legislators that not only do not understand, but do not care, except for the partisan appeal of some special interest.

Something with the fundamental quality of the common law must be at the basis of every great development in civilization, and some such process must be used to make the necessary adjustments in our industrial development. But with our rapid life of today we cannot wait for such slow unfoldings of public opinion. We must secure the same results by an accelerated process. A body of standards developed by a body of experts that represent all interests and that work in constant contact with the facts is our modern substitute for the common law, and if such standards are conscientiously and intelligently formed they should have much the same qualities as the common law.

It is obvious that with our increasingly complicated and inter-dependent industrial civilization, there must be a mass of technical questions of a public and semi-public character that must be adjudicated, matters involving the inter-relations and accommodations of various industries with each other and with the public, such matters for instance as the crossing of tracks by high-tension transmission lines, the interference among the various uses of wires and of the air, questions involving the properties of materials and their proper use.

If the courts are to be used for the adjudication of such questions as these, it can only be at large expense and with great inefficiency and resultant dissatisfaction. A court is essentially an inexpert institution. It is not naturally fitted to handle technical problems. Industry for its own best good must see that a basis for such adjudications is built up on an expert technical non-legal basis. Most of such questions will then not get into the courts and where they do, the courts will be inclined to confine themselves to the more strictly legal phases of the cases depending for technical guidance upon the standards of industry provided they represent the consensus of opinion of all interests.

LIFE TESTS OF INCANDESCENT LAMPS

During the past month life tests of 115 gas-filled lamps have been started, and the tests of 442 vacuum, 112 gas-filled and 12 carbon lamps have been completed by the Bureau of Standards.

The only lamps now remaining to be started on test are 86 50 and 60-watt lamps, part of a group on which a series of readings covering change of reduction factor during life are being made. The work for the present fiscal year will soon be completed and a summary will appear as usual in the annual report of the Director of the Bureau.

The results so far obtained show that the lamps furnished by all the contractors have been of a very satisfactory quality, in many cases exceeding the requirements of the specifications.

Operating Experiences with the Relaying of the Duquesne Ring

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***Review of the Subject.**—A paper was presented by the writer at the A. I. E. E. Spring Convention, held at Pittsburgh, April 24 to 26, 1923, and was published in the July 1923 issue of the Institute Journal, on the subject; "Selective Relay System of the 66,000 Volt Ring of the Duquesne Light Company." That paper described in detail the systems of relaying which are used to protect the Duquesne Ring for both short circuit and ground faults. That paper also described the service tests which were made on the ring to test the relay protection.*

Nearly a year has passed since the ring was put into operation with the protection described, and ample opportunity has been given to study the protective schemes under actual service conditions and to prove their practicability. This period of service has included one of the worst, if not the very worst, lightning seasons that has ever been experienced in the history of the Duquesne Light Company. Electrical storms in the Pittsburgh District are unusually severe, both as to intensity and duration, due probably to the geographical location of the district, situated as it is at the junction of two rivers. Storms in this vicinity almost invariably seek the Ohio River Valley and follow it up to the point of junction of the Allegheny and Monongahela Rivers, after which they will continue up one of these streams. Storms of several hours duration are not at all uncommon during the height of the lightning season. These have resulted in many insulator flashovers during the past season, and the ground relays have given an excellent account of themselves. Several line short circuits have occured, and the proper relays functioned correctly in every case.

This paper gives a partial log of relay operations on the ring for the first eleven months' service, and it will be noted that every case of trouble on lines has been cleared by the proper relays. A study of all operations leads to certain conclusions as to the proper means of improving the present protection, and these are described in detail. All troubles and difficulties have been frankly described and nothing withheld. It is hoped that other operating companies, which are using, or contemplate using, similar types of protection may derive some value from the discussion and data presented.

THE Duquesne Ring consists essentially of a double-circuit 66,000-volt loop surrounding the City of Pittsburgh. (See Fig. 1). Its circumferential length is approximately eighty miles, and the two circuits are paralleled and sectionalized at six step-down sub-stations, and two generating stations. Power is fed into the ring at opposite ends by the Colfax and Brunot Island power plants, the capacity of each plant being 120,000 kw.

The short-circuit protection of the lines is secured by the use of cross-connected reverse-power Westinghouse Type "CR" relays. The ground protection is effected by means of balanced-current Westinghouse Type "CD" relays connected in the neutral of the balanced lines. These lines are balanced in pairs in every case except at Junction Park, where no balance is made, and where straight reverse power protection with interlocked overload relays for directional ground protection is used.

Fig. 1—Map of the Duquesne Ring

The busses and transformer banks at each station are protected by differentially-connected overload relays. The low-tension busses are protected by means of overload relays only on the low-tension transformer breakers.

The line protection is shown diagrammatically in Fig. 2; a relay diagram of the system is shown in Fig. 3; and a schematic diagram of the relay protection of a typical station is shown in Fig. 4.

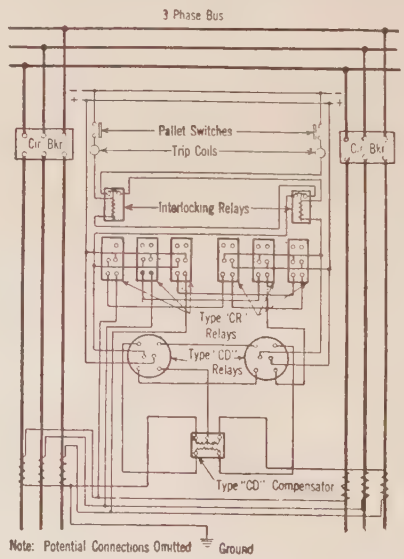

Fig. 2—Diagram of Connections of Line Relays

The relay settings used during the past year were as follows: Line short-circuit relays, 7-ampere current tap; 0.4 second definite minimum time; current transformer ratio 400/5. This requires an unbalance

Abridgment of paper presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-10, 1924. Complete copies to members on request.

of 560 amperes between balanced phases to operate the relays, and since each 4-0 circuit is rated at 30,000 kw., this allows each circuit to carry 200 per cent unbalanced load before tripping. As the minimum short-circuit current on the system is approximately 3000 amperes, this leaves an ample margin of safety.

The line ground relays are set to operate on an unbalance of 40 amperes. As the minimum ground current is approximately 600 amperes, positive operation of these relays is assured. The ground current on the 66,000-volt system is limited by the 63-ohm ground resistor at each of the two generating stations.

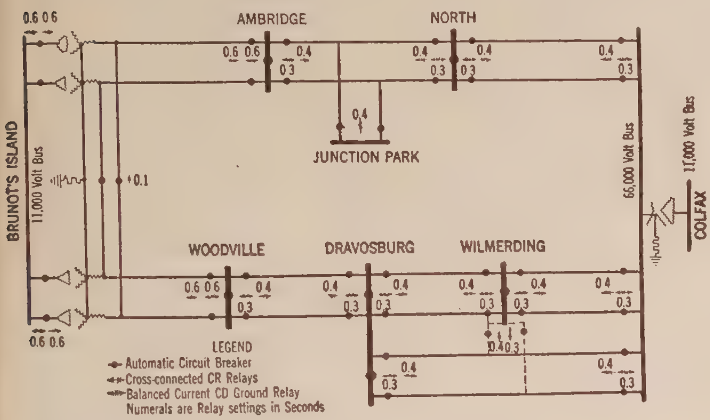

Fig. 3—Schematic Diagram of 66-Kv. Ring System, Showing Relay Protection of Lines

The high-tension bus differential relays are set to operate on 0.7 ampere current tap, 0.75 second. With 400/5 current transformer ratio, this causes these relays to operate on a minimum of 56 amperes, which allows the same relays to give short circuit and ground protection on the busses. The value of the time setting for the differential relays was arrived at after several incorrect operations of bus differential relays had occurred. It was observed at certain stations that the bus relays would operate each time that a line fault occurred adjacent to that particular bus. The line relays would first operate correctly to open the line breaker. Immediately, as soon as the line breaker opened, the bus differential relays, which were then set at 0.1 second, would close contacts and isolate the bus. The cause was readily surmised and proved by test to be due to the action of the pallet switch of the breaker. This is a heel and toe switch, the function of which is to operate mechanically when the breaker is opened, to short circuit the current transformers in the breaker and to open the parallel circuit of these current transformers with the transformers in the breakers remaining in circuit on the bus, thus leaving a true balance on the bus differential relays. Thus, when the breaker opens under load or short circuit, it is necessary that the are on the breaker contacts be broken simultaneously with the operation of the pallet switch contacts. Any timc difference which may exist will create an unbalance in the bus differential relay circuits, and if the time of duration of this unbalanced condition is equal to or greater than that of the time setting of those relays, it is obvious that they will close contacts. As the time of duration of the arc in the breaker is problematical, and will vary somewhat with faults of different characteris-

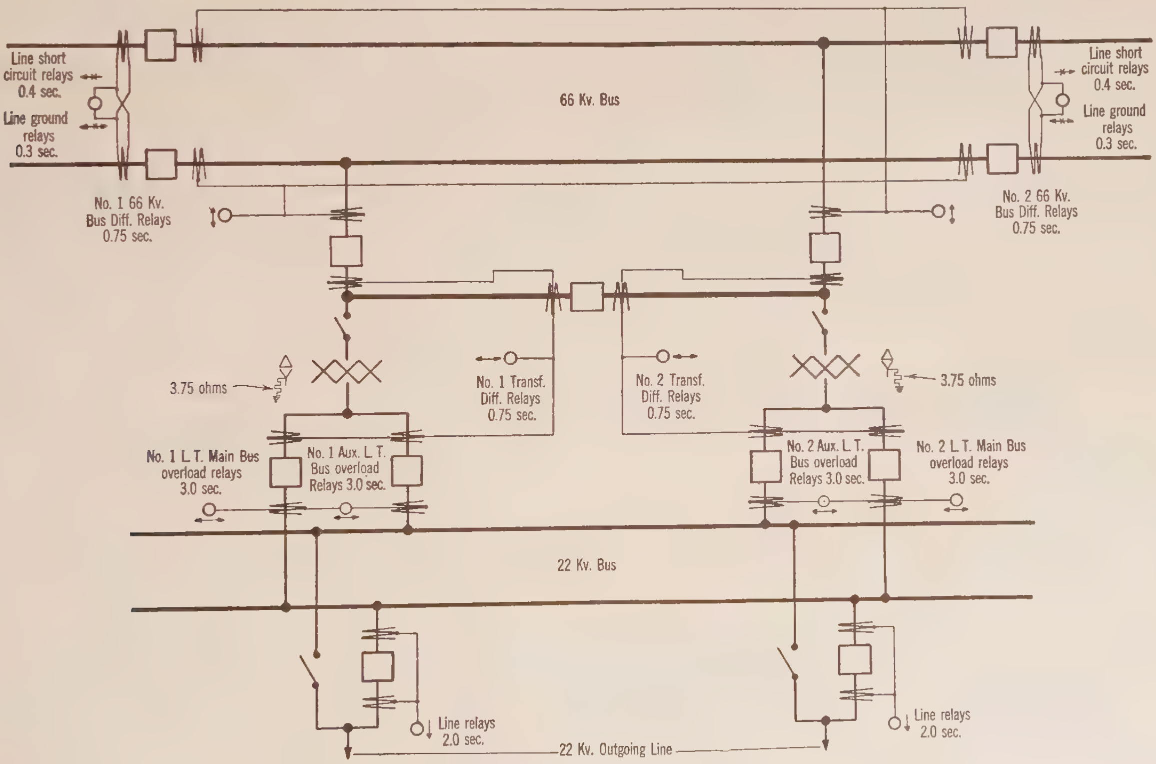

Fig. 4—Schematic Diagram Showing Relaying of Typical Substation-Present Layout

TABLE I—LOG OF 66-KV. RELAY OPERATIONS

Case No.	Date	Cause	Breaker Openings	Relays Operated	Correct Relay Operations	Incorrect or Unaccountable Relay Operations	Total Relay Operations	Remarks
13	6-22-23	Electrical storm. The fault was on North-Ambridge No. 1 line.	North - Ambridge No. 2 at North	CD	1		1	It is believed that this occurred simultaneously with Case 12, and is therefore correct, as the two lines were running in series, since North-Ambridge No. 1 was open at North at the time. No load lost.
14	6-22-23	Electrical storm.	North-Colfax No. 1 at North North-Colfax No. 1 at Colfax North-Colfax No. 2 at North North-Colfax No. 2 at Colfax	CR CR CD CD	4		4	This was caused by a direct stroke of lightning on a tower. See discussion in text. No load lost.
21	7- 6-23	Electrical storm	North-Ambridge No. 1 at North North-Ambridge No. 1 at Ambridge North-Ambridge No. 2 at North North-Ambridge No. 2 at Ambridge Jct. Park-Ambridge No. 2 at Jct. Park Brunot Island - Ambridge No. 2 at B. Island Brunot Island - Ambridge No. 2 at Ambridge Brunot Island - Ambridge No. 1 at Ambridge	CD CD CD CD CO CD CD	7	1	8	All of these breaker openings were simultaneous or nearly so. The only incorrect operation was the opening of Brunot-Island No. 1 at Ambridge, and its cause is unknown, but would seem to point to improper operation of the interlocking relay. Local load lost at Ambridge and Jct. Park.
29	9-10-23	Lightning - arrester lead broke loose on Brunot Island-Woodville No. 1 and swung into adjacent phase at Woodville; simultaneously, a strain insulator flashed over at Woodville on Brunot Island-Woodville No. 2.	Brunots Island-Woodville No. 1 at B. Island Brunots Island-Woodville No. 1 at Woodville Brunots Island-Woodville No. 2 at B. Island Brunots Island-Woodville No. 2 at Woodville	CR CR CR CR	4		4	See text for further discussion. All synchronous load was lost.
34	11-20-23	Breaker bushing failed on No. 2 line at Jct. Park, and involved the tie disconnects.	Jct. Park-Ambridge No. 2 at Jct. Park North-Ambridge No. 2 at Ambridge North-Ambridge No. 2 at North North-Ambridge No. 1 at Ambridge North-Ambridge No. 1 at North	CO CD CD CD CD	5		5	No load lost, as low-tension bus remained hot from loop feeders.
37	12-16-23	Insulator flashover at Jct. Park, on No. 2 line.	Brunot Island - Ambridge No. 2 at B. Island	CD	1		1	This occurred simultaneous with case No. 36 and was an unnecessary operation, and was due to the fact that Brunot Island-Ambridge No. 1 was out of service for repairs. This opened the ring between Brunot Island and Ambridge but no load was lost, as Ambridge was carried from North.
40	1- 7-24	Bus short circuit on No. 2 transformer bus at Dravosburg, caused by failure of line breaker.	No. 1 Trans. breaker at Colfax No. 2 Trans. breaker at Colfax	CO CO	2		2*	The transformer differential relays did not operate, and the trouble was removed by the operator at Dravosburg by hand. All load lost.
44	1-16-24	Bushings failed on both sides of No. 2 breaker at Junction Park.	North-Ambridge No. 1 at North North-Ambridge No. 1 at Ambridge North-Ambridge No. 2 at North North-Ambridge No. 2 at Ambridge	CD CD CD CD	4		4	Lost local load at Junction Park.

*One failure.

tics, and moreover as the heel and toe pallet switch has a brief period during which the blade is closed on both sets of contacts to avoid open circuiting the current transformers, it is therefore obvious that some period of current unbalance will exist each time a breaker opens. It is therefore necessary to set the time of the bus relays in excess of any such possible discrepancy. The maximum time difference found was between 0.2 and 0.3 seconds. The setting of 0.75 second therefore has a considerable factor of safety.

The transformer differential relays are set at 0.7 ampere current tap, and 0.75 second definite minimum time. The same condition of unbalanced currents will exist on these relays when one of the breakers in this differential opens, as in the case of the bus differential relays, discussed above.

The low-tension bus overload relays are set for a current tap which will allow the bank to carry 200 per cent load without tripping; and a time setting of three seconds. This time setting is used to be selective with the two-second settings on the outgoing feeders from the low-tension bus.

Table I gives a portion of the log[1] of relay operations on the ring for the eleven months period, March 15, 1923 to February 15, 1924. During that time a total of 39 line faults occurred, all of which were successfully sectionalized by the relays. Of these 39 faults, it is interesting to note that 12 were short circuit and 27 were ground faults. In every case of line fault the trouble was successfully sectionalized by the ring relays, and the ring was left intact. The ring was opened at one point several times, but the other side remained closed and the power plants were not separated by the action of the automatic relays. Some of the cases, however, involved operations which were unnecessary, and some which were not entirely accountable. One failure was experienced.

The following general divisions may be made of the total number of cases of trouble which occurred on the ring:

Total faults on the ring	43
Faults giving 100 per cent correct relay operation	36
Faults involving incorrect or unnecessary relay operations	6
Faults involving relay failures	1

An analysis of the above leads to some interesting conclusions. First, of a total of 43 faults which have occurred on the ring, all but one have been successfully cleared by the relays. This gives an overall efficiency for relay operation of 97.7 per cent. It is also interesting to note that five of these faults were double circuit faults. These are recorded as cases 14, 21, 29, 34 and 44. It is obvious that this is the worst type of fault to encounter with a system of balanced protection, which depends inherently upon the inequality in fault energy in the balanced circuits. Yet, in each of these cases both defective circuits were successfully removed from the system. Three correct operations have occurred on transformer differential protection. On the basis of relay operations, a total of 108 have occurred, of which 87 were correct and 21 incorrect or unaccountable.

Several cases have occurred during electrical storms where one balanced ground relay has operated to trip the breaker on one end of a line. The other end remained in service and there was no fault remaining on the system. This would indicate that the ground fault had been cleared by a single breaker opening but no explanation of this has been found.

The hazard of unnecessary breaker openings on a system of this kind is very clearly shown in Cases 13 and 37. In each of these cases one line of a balanced pair had been automatically opened at both ends, due to a line fault, or else the one line was out of service for repairs. Under these conditions, a fault occurred on another section of line, and this caused the good section of line, operating singly, to open at the feeding end, as all relays are set to operate in a given time, which is, of course, the same for either single or double-line operation. These operations resulted in splitting the ring open on one side, which, however, did no harm, since the ring was closed on the other side. If, however, the ring had been operating with a single-line section on both sides, and a fault had occurred, it would have opened both single-line sections and separated the power plants. Obviously, the lesson to be learned from these cases is that single-line operation must be automatically rendered selective with the remaining balanced sections. This may be called Modification No. 1 and is referred to later.

Two other cases of trouble have been experienced which may prove of particular interest to users of balanced protection, and which have led to Modification No. 2. These cases both have to do with the use of interlocking relays. These relays, which are shown in Fig. 2, are connected in the conventional manner, so that the automatic tripping of breaker No. 1 on a pair of balanced lines operates the direct-current interlocking relay on line No. 2. The contacts of this relay open instantaneously, and lock out the tripping circuit of its breaker until a definite time interval has elapsed, after which time it is restored. This time interval is sufficient to allow the faulty line to clear at the opposite end and thus remove the fault from the system. If some such precaution is not taken, it is obvious that the good line of the pair will open at No. 1 end simultaneously with the opening of the bad line on No. 2 end. It is evident that the success of this scheme depends entirely upon the proper functioning of the interlocking relay. If this relay fails to trip, the good line of the pair will be incorrectly opened. If this relay trips but fails to reset, the second line is left without protection at that end. Both of these

1. A complete log of 66-kv. relay operations, on which this paper is based, can be secured by reference to the author.

conditions have been found to exist, although fortunately under test and not service conditions. At best, a direct-current time relay requires considerable maintenance, and the timing feature is not accurate. For the latter reason it is desirable to set them for a liberal time interval, so as to assure the positive clearing of the bad line at both ends to hold the good line in service. For this reason, and because the particular type of interlocking relays supplied were especially accurate and dependable at that point, these relays, as used in 1923, were set for a re-setting time delay of eight seconds. Under these conditions, two cases occurred involving the operation of the relays.

Case 14 occurred during a severe electrical storm in July. A stroke of lightning hit at or very near one of the 66-kv. double-circuit steel towers about one-half mile from the North Substation on the North-Colfax lines. The severity of the discharge is shown by the fact that on the following day it was found necessary to replace 20 suspension insulator strings on this line in the vicinity of the stroke. At the tower struck, all three insulators flashed over on No. 1 circuit, and at least one insulator string on No. 2 circuit. This action presumably was simultaneous. The operators at both North and Colfax report that both lines opened simultaneously. This is, of course, theoretically possible, assuming a three-phase short circuit on one line and a single-phase ground on the other line, in which case the short-circuit relays on one line and the ground relays on the other line would be unbalanced and operate simultaneously. To do so, it would be necessary for both sets of relays to close before the interlocking relay had operated to render one line temporarily non-automatic. Moreover, it will be noted that there is a difference of 0.1 second in the time settings of the short-circuit and the ground relays. Hence, it is highly probable that the short-circuited line opened first and the ground circuit remained on No. 2 line during the 8.0 second period that this line was rendered non-automatic, due to the proper functioning of the interlocking relays, and that this line was tripped as soon as the trip circuits were restored. No distress, however, was apparent on the system, except a severe voltage dip when the initial short circuit occurred.

The next cast was not so fortunate. This is recorded as Case 29. The initial fault was occasioned by a lightning-arrester lead coming loose at the Woodville Substation platform and swinging into an adjacent phase of the Brunot Island-Woodville No. 1 line. The short-circuit relays functioned properly, and the line was cleared at both ends. However, almost simultaneously with the short circuit on No. 1 line, a fault developed on a strain insulator at Woodville on Brunot Island-Woodville No. 2 line. This line was then non-automatic by the action of the interlocking relays, resulting from the opening of No. 1 line. The fault on No. 2 line developed almost immediately into a short circuit and for eight or nine seconds the system was in distress. The voltage dropped to a low value and the two power plants hunted, resulting in considerable surging. At the end of the eight second period, the interlocking relays restored the trip circuits of the line and its was tripped automatically at both ends. All synchronous load was dropped, but no other damage resulted, nor did any simultaneous failures develop. As a consequence of this breakdown, resulting as it did in sustained distress, it was decided to reduce the time delay on the interlocking relays from eight seconds to four seconds. Since that time, two similar cases of trouble have developed, cases 34 and 44, and no particular distress has occurred on the system, only a small part of synchronous load was lost, and that only in the immediate vicinity of the trouble. As previously stated, these two occurrences resulted in the adoption of Modification No. 2.

A third and fourth modification have been made as a result of Case 40. This resulted in the only failure to date of any of the 66-kv. relaying, and it is interesting to note that the failure occured on differential apparatus protection rather than on the balanced line protection, where perhaps the probability might be considered greater, particularly considering the larger number of operations which occurred on the line relays. This failure was the result of a rather extraordinary sequency of events which could hardly be foreseen. A 22-kv. line breaker was closed on a fault to test the line, after the breaker had opened once automatically. The breaker apparently cleared the fault at the contacts, but threw fire and oil from the vent in the tank. This caused a short circuit on the bus side of the breaker bushings, and the overload relays on the low-tension bank breaker operated to trip the breaker. The 22-kv. bus was split at the time. This breaker failed in opening, blowing off two tanks and short circuiting the low-tension side of the transformer bank. This placed the fault within the bank differential protection, which failed to operate. The fault was cleared when the operator stripped the board, opening all high-tension switches. An investigation later showed the transformer differential protection to be in perfect condition. A very thorough investigation brought forth the following explanation, which, however, could not be definitely substantiated, since the evidence was destroyed. It seems probable that when the transformer breaker was tripped, the breaker did not fully open, with the result that the heel and toe pallet switch remained in the neutral position. This left the differential relays short circuited and hence inoperative, thus accounting for their failure to close contacts.

As a result of the experiences to date with this relay system, certain conclusions have been reached as follows:

1. It must be possible to operate the ring with one or more single-line sections in circuit, without danger of dropping these sections when faults occur on other sections. (See Modification No. 1).

2. Some system of interlocking must be used which will be capable of more accurate time settings than the present, and especially one whose failure to function properly cannot leave any lines without protection. (See Modification No. 2).

3. Every system of primary relaying must be provided with a system of back-up protection which will act if the first system fails, a "second line of defence," as it were. These features are now being applied to the ring, and are described in the following, under Modification No. 3.

4. Means must be provided to give protection for faults occurring inside the tanks of circuit breakers. (See Modification No. 4).

5. It must be possible to automatically remove any single unit from service at a station without killing this station. (See Modification No. 5).

Modification No. 1 consists of the addition of a set of overload relays, which are automatically thrown into service when one line of a pair is removed from circuit. These relays then give overload protection on the remaining line, and their time is set high enough to be selective with the remaining fast-time balanced relays. This will prevent the unnecessary opening of all good single-line sections when faults occur on the other paired sections. At the same time, the single-line sections are left with ample protection for themselves. The modified protection is shown schematically in Fig. 5. The balanced line protection is the same as before, shown in Fig. 2, except that the direct-current time-delay-closing interlocking relay has been eliminated. This relay has been replaced by an instantaneous direct current multicontact relay whose coil circuit is closed by a pallet switch on the breaker when the latter is open. The function of this multicontact relay is to automatically throw into circuit the trip contacts of the long time overload relays whenever a line breaker has opened. Under normal conditions, with both balanced lines in service, the tripping circuit of the instantaneous balanced directional relays passes through the back contacts of the two multicontact relays in series. But when either breaker is opened, the back contact circuit is opened and this removes the short circuit from the trip contacts of the long time overload relays and the circuit of the breaker trip coil must pass through these long time relays in series with the contacts of the instantaneous bald ancedirectional relays. Thus selective directional single line protection is automatically supplied to each line when the other line of the pair is out of service. By this means the entire ring may be operated single line if necessary and selective disconnection of defective circuits obtained.

Modification No. 2 follows as a consequence of Modification No. 1, and secures the employment of accurate and dependable interlocking relays. This is accomplished by the same relays as were added in the preceding modification to secure selective single-line operation. The time delay is secured through the action of the long-time back-up alternating-current overload induction relay, which is automatically thrown into service when one of the balanced lines is tripped out, either automatically or otherwise. This relay starts to trip out the good line, but the bad line clears at the other end before the long-time overload relay can close contacts. This scheme has the additional features:

1. That the good line is never rendered non-automatic;

2. That the failure of the direct-current relay, either to close or open, does not cripple any protection, but merely destroys the selectivity;

3. That all units in the interlocking scheme are very positive in their operation;

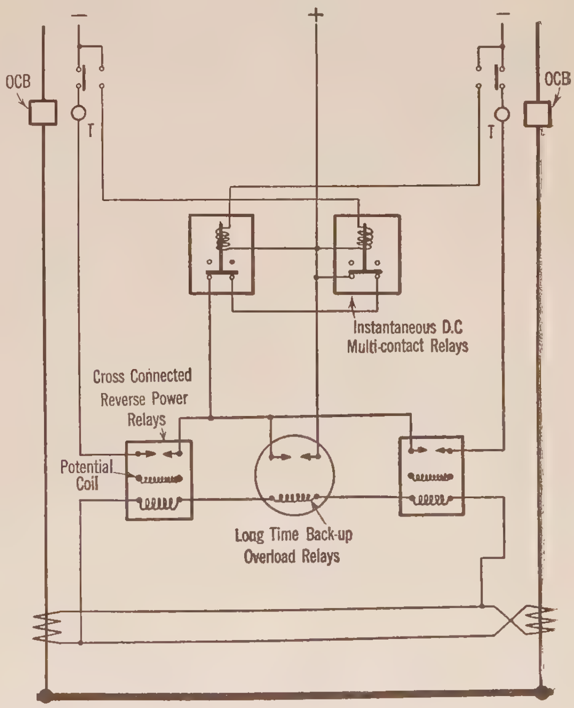

Fig. 5—Schematic Diagram of Improved 66-Kv. Line Protection

4. That very accurate time-setting of the interlocking feature is accomplished.

Modification No. 3 has been adopted to secure a second line of defense to two different systems of relaying: the line relays and the station protection. This is shown in Fig. 6, and consists of reverse-power relays on each 66-kv. transformer breaker, set to trip for power flowing from the ring to the station bus. The trip circuits of these two sets of relays, however, are crossed, that is, the relays on No. 5 transformer breaker trip breaker No. 6, and the relays on No. 6 transformer breaker trip breaker No. 5. This is done to secure back-up protection for the line circuit breakers, and is accomplished as follows. Referring to Fig. 6, let us assume that a fault has developed on the upper right hand line. The breaker at the other end has opened.

correctly but breaker No. 1 at this station has for some reason failed to open automatically. This places a balanced fault on the ring, which cannot be detected by any of the remaining balanced types of protection. Such an occurrence would shut down the system, unless special means were provided to relieve it. This is accomplished by the No. 1 66-kv. bus-splitting reverse-power relays which respond to the power which will pass over the bus tie feeding into the fault through line breaker No. 1. These relays will trip breaker No. 6, which leaves all the station load on the good line, and by splitting the bus, has taken the balance off the lines. This passes the trouble back to the next adjacent station, where the line relays will operate to clear the fault from the system. The second function of tion is to prevent a 22-kv. bus short circuit from killing the station. It consists of the installation of a bus tie breaker in the main 22-kv. bus, and the protection of each section of this bus by means of bus-differential relays. (See Fig. 6.) An additional set of over-load relays is inserted between these busses to act as bus-splitting protection. The purpose of this is to complete a second line of defense for the 22-kv. outgoing line breakers. Thus if line breaker No. 14 fails to open for a fault on its line, this will put the trouble on No. 2 section of the 22-kv. bus, which will then be cleared by the operation of the bus-splitting overload relays opening bus tie breaker No. 12 and the operation of No. 2 main bus overload relays opening breaker No. 11. This will clear the fault from the system and leave the sta-

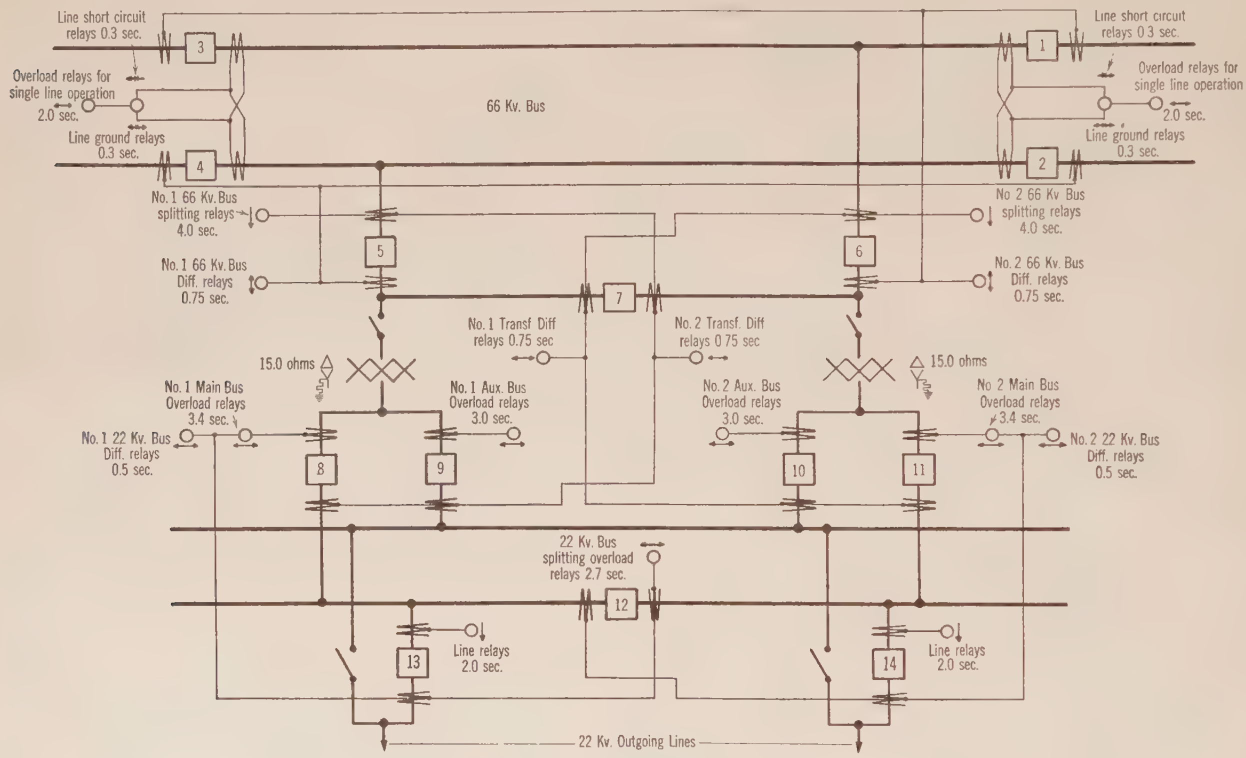

Fig. 6—Schematic Diagram Showing Relaying of Typical Substation—Ultimate Layout

these bus-splitting relays is to act as back-up protection for any faults which may occur at the station. Thus, if any of the bus or transformer differentials fail to function properly when in trouble, these relays will act as overload protection to take the trouble off the ring. Modification No. 4 has been adopted to take care of faults inside breaker tanks. It is done, as shown in Fig. 6, by overlapping the protection around each circuit breaker. Thus, on a line breaker, the relays are connected to the current transformers on the bus side of the breaker, and the bus differential relays are connected to the current transformers on the line side of the breaker. Thus, a ground fault inside a tank will operate both the line and bus relays, and thus clear both sources of feed to the fault.

Modification No. 5. The purpose of this modification hot on the No. 1 section of the low-tension bus. If the fault had been on the bus itself, such as by the failure of a line breaker No. 14, this would have operated the No. 2 22-kv. bus differential relays and opened breakers 11, 12, 14 and the breakers of any other outgoing lines from this section of bus.

As a whole, the performance of the ring relaying during the past eleven months is considered extremely successful. Of a total of 43 major faults which developed, 42 were successfully sectionalized and only on two occasions was a major outage permitted to result. The single failure which occurred was the result of defective apparatus which could not be controlled. This contingency will be eliminated in the future by the safety valves which are being added. The action of the balanced line relays has been very pleasing. All

cases of line trouble have been relieved with a very small amount of damage and disturbance. This is, of course, due to the sensitivity of the relays and their rapidity of action. Every case of insulator flashover during the past season has been disconnected so quickly that a negligible amount of injury has resulted at the fault and the lines were returned to service in every case under adverse conditions. This even includes the case of the direct lightning stroke of Case 14, where, although considerable damage was done to the porcelain, it was nevertheless possible to put the lines back into service immediately as the copper was practically undamaged.

It is confidently believed that the performance of the ring to date will compare extremely favorable with any equivalent system during the same time. It is further believed that with the additional safety features added, as described in this paper, the coming year will considerably better the record to date.

Discussion at Midwinter Convention

GASEOUS IONIZATION IN BUILT-UP INSULATION—II[1]

(Whitehead)

Philadelphia, Pa., February 5, 1924

F. M. Farmer: I just want to mention one thing you may be interested in. Dr. Whitehead has referred to the critical point in the curve between the dielectric losses and voltage. It is proposed to use this characteristic in a practical way in connection with paper-insulated cables. As you all know, a paper-insulated cable is an impregnated laminated structure, and we have always felt that an important element in the satisfactory operation of such a cable is thoroughness of impregnation. The question is, How are we going to tell when the insulation is thoroughly impregnated, that is, free from moisture and voids?

It has been proposed that we use this critical point. (Illustrating on the blackboard). A little easier and more practical method is to use power factor, instead of voltage. Normally the curve between power factor and voltage is horizontal with the abscissa, up to this point which Dr. Whitehead has called the critical point. At that point the line will depart. This point is generally referred to as the point where ionization begins.

Now, if ionization is a matter of variation in impregnation, we get some kind of a measure of impregnation by the slope of this curve, particularly the slope of this line beyond the critical point,—in other words, the change in power factor with a given change of voltage.

It is proposed that such a test could be applied to every reel of high-tension cable as a test of thoroughness of impregnation. It is a test that can be made fairly easily, and is a perfectly practical one, but the question still in the minds of a good many of us is just how important is it? We need quantitative information as to just how significant a given change in the slope of this line is as an indication of the quality of the insulation.

Dr. Whitehead's experiments seems to show ionization produces a destructive effect. But we need more experimental evidence before we can draw definite conclusions because there seem to be a good many cases where high voltage cables have been in service for many years at a voltage considerably above this critical point or ionization voltage without giving any trouble whatever.

Everett S. Lee: Professor Whitehead in giving his paper has attempted to make a statement regarding practically all of the variations which have come about, and in most cases I think we can say that we would agree with him. In other cases, other statements might be made that would equally fit the case, particularly in connection with the insulation resistance. Although I noted that in his remarks he cautioned us about making too much use of it, I just want to dwell on that point for one moment because it does seem that in the results which he obtained, the insulation-resistance curve, as shown in Fig. 1 did seem to show in an inverse way, about the same thing as the loss curve showed.

Now, if that is true, it is just one more phase in the insulation game which makes us pause and consider, because of the fact that the losses were obtained at 60 cycles, at a potential of about 5 kv., whereas, the insulation resistance was obtained with dire electromotive force of about 200 volts, the time of application being about one minute.

In other words, if we can connect up quantities obtained under such widely varying conditions, it is very interesting indeed, and the only way we can really determine it is to examine closely all of the available data to see if that is true. I know in a great deal of our experience we have come to the conclusion that we could not tie up these two factors, and although it has been done in Professor Whitehead's paper to some extent, I think the statement that he made in his paper bears the conclusion out that so far anyway we do not have a good direct relation between the two quantities of insulation resistance, taken as we take it, and dielectric energy loss obtained, as we take it.

I was impressed, upon reading the paper, that on making the measurements of loss, it was almost impossible to obtain them, because of the fact that the loss increased considerably even in a few moments, causing an increase of temperature which we know is cumulative, higher temperature resulting in higher loss, and even going so far as causing two of the samples to break down.

It is quite significant to note that one sample which broke down had practically the lowest loss of all, and there again we find a condition here which we meet in practise, That is, we have material which has a very low loss and yet we find its dielectric strength may also be low.

The general law, therefore, from our experience seems to be, that if we have relatively high loss we may expect low dielectric strength, whereas, if we have low loss we will not necessarily get high dielectric strength. There seems to be a point of low loss beyond which it is not necessary to go, to have high dielectric strength.

Further, in connection with the paper and also in connection with what Mr. Farmer has said, I would call to your attention the use of the property of power factor. If we express our results of tests upon insulation in terms of loss, in order that we may compare the results obtained by one observer with those obtained by others, we must know the exact physical dimensions of the samples, and it is very important because the loss measurement gives the total loss in the sample, and that will be determined by the size of the sample, the manner in which it is built up, the manner in which the voltage is applied, the kind of electrodes, etc.

Now, we have a property which, although varying to some extent, eliminates quite a few of those factors, and that, I believe, is the property of power factor, and if we could use power factor in our results, I believe it would come nearer to being a term which when one observer expressed his results as such and such a power factor, it could be used by other observers in comparing their results.

Now, if that is true (and I hope we may have other discussions on that), I believe it would be well worth while for us to consider

1. Part I published in pamphlet form only, Part II, Jan. 1924.

that, because as I understand it, the insulation section of the engineering division of the National Research Council is interested in having available as far as possible the results of different observers, and if we can agree on some term in which we can express our results, so that they will be more nearly comparable, that of itself will be a step in advance.

W. A. Del Mar: There are two elements in research work which I think are not always recognized. The first element is the gathering of information, *i. e.*, the building up of knowledge in experimental work.

The other element is the inspirational, where the subconscious mind brings these data into juxtaposition and produces a new idea. Real progress in research cannot be made without these two elements.

Thus far, insulation research has been mostly of the former type, but the insulation problem is not like many of our problems, a matter of discovering some equations or series of equations which will give an answer to our questions. We are concerned with something that is very complicated, involving the effect of small quantities of air, small quantities of moisture, and the motions of exceedingly small particles of matter. We also have chemical problems. When there is ionization, nitrous oxide and ozone are formed, both of them exceedingly active chemically, and Professor Whitehead has shown us how those materials affect the insulation; but there is another effect that ionization produces. It changes mild surface leakage into streamer discharges thus setting up local surges of an exceedingly high frequency, and often of a violent character. It may be that most, or possibly all cases of laminated insulation failure are due to those local surges. It seems to me doubtful whether the actual voltage that you measure on the voltmeter is the real voltage that causes the disruption at a given point in the insulation. I think in every case there is a local gradient which is not measured on the instruments.

In the matter of cable performance, this matter of ionization is, as Mr. Farmer pointed out, a very live question. There are cables, to my knowledge, which are working with considerable ionization and working satisfactorily. There are others which are failing and apparently the failure is due to the presence of air. We don't understand the reason why in some cases the air seems to cause trouble and in other cases it does not. There is a big field for research work of a very interesting and important character. Mr. Whitehead's researches on ionization show a thorough realization of the vital point of attack in the insulation problem.

P. L. Alger: In looking over Mr. Whitehead's paper, I thought it would be interesting to bring out the relation between the state of the art as indicated by his results, and the parallel arts of cable insulation and condenser insulation. It is customary, I believe, in the manufacture of cables to operate at a voltage stress of perhaps fifty or sixty volts per mil and to have a power factor of five per cent or less. In condensers made of oil and paper it is usual to operate at several hundred volts per mil and to have power factors of one-half of one per cent, whereas in Mr. Whitehead's paper the experiments show a stress of perhaps forty volts per mil under normal conditions and a power factor of perhaps two-tenths. Of course, there are differences in the manufactures of the different types of apparatus which partly account for these differences in stress and power factor—for example in cables the insulation is protected from air by the outside sheath.

In armature coils the insulation is exposed to air, and therefore moisture and oxidation both give trouble. But I believe the major part of the differences is due to the fact that the binder used in the armature coil insulation is ordinarily some kind of shellac or other material, which is not physically stable at normal temperatures and which gives off volatile gases or boils at temperatures of fifty deg. cent. or more.

For this reason I feel that such a power factor-voltage curve as Mr. Farmer has drawn is not entirely reliable unless the temperature around the cable is lowered as the voltage is raised so as to preserve the same temperature inside the insulation throughout the tests. In this way only will a true curve of power factor against voltage that is independent of the temperature be obtained. I feel that the rise of power factor with temperature shown by Mr. Whitehead is due to the boiling away of some of the sticker or compounding material used, and consequently, that the best way to advance in this armature insulation art is to study the stability of the materials used under high temperatures. No electrical tests at all seem essential until a material is found which is satisfactorily stable and which will not give off gases until after temperatures of perhaps one hundred degrees are attained.

Alexander Nyman: I was particularly struck by the statement of Mr. Whitehead that on applying the pressure to insulation, the losses due to corona effect were reduced.

In building static condensers, particularly of the mica type, this effect is very pronounced. We find that in making condensers we have to apply the pressure whether mica or paper is used as insulator.

We have made samples of condensers where it was possible to observe the corona effect, visually, and we found in these condensers that even with the highest pressure applied, although the corona effect was reduced, it was not eliminated at high voltages, except by a special construction.

The only way to minimize the corona effect is to fill up all the smallest crevices in the insulation, with some other insulating compound, wax or varnish or anything that will eliminate air entirely. It is therefore necessary not only to apply the pressure, but also to evacuate the particular piece of apparatus and then impregnate it with the necessary material.

I would very much like to know what pressure Mr. Whitehead applied to the insulation in order to eliminate the losses altogether. The reason for the corona losses disappearing on this curve is, I believe, that the dielectric losses are large, and when you apply the pressure although the corona losses are not eliminated, they are so small that they become negligible compared to dielectric losses. In static condensers where the insulation is pure mica, the dielectric losses are small and the corona losses become important even at very high pressures.

In paper condensers, the effect is exactly the same as in mica condensers. You must not only apply the pressure but also fill in all the minutest spaces with some impregnating compound. There are different types of paper used in static condensers. For instance, I believe that some condensers have been manufactured with paper which has been impregnated before applying the condensers. I believe this is a mistake.

In general it will be found that with that kind of paper, although you can eliminate most of the air spaces, you can't eliminate all of them and there will still be losses. It is only a paper that can be impregnated throughout by some suitable compound that would give reduced losses.

I believe this will possibly shed some light on cable construction as well. I heartily agree with the statements of one of the speakers on the use of power factor in determining the quality of an insulation as far as dielectric losses are concerned.

Herman Halperin: Dr. Whitehead has stated that the $I^2 R$ loss in insulation is a small part of the dielectric loss and I understood Mr. Lee to say that the insulation resistance did not give any indication of the dielectric loss.

It has been found for the impregnated paper insulated cables bought for the Commonwealth Edison Company that as long as the manufacturer was using about the same kind of impregnating compound and paper, a curve of dielectric loss versus insulation resistance, similar to the one below, would be obtained.

I wish to agree with the other speakers in regard to the value of plotting the power factor of the charging current instead of dielectric loss, against voltage. As a matter of comparison between the various kinds of built-up insulation on cables, it might be well to use the maximum dielectric stress in the cable for the

abscissa instead of the voltage, since it appears that the ionization in the cable starts at some definite dielectric stress for a given insulation.

I also want to emphasize the remarks made by one of the speakers as to the great value of any investigations along the lines of dertermining the effect of this ionization loss on the life of the insulation.

H. L. Curtis: One of the most interesting points in Dr. Whitehead's paper was his statement that he had come to the conclusion that there is no definite relationship between insulation resistance and dielectric loss. That is quite generally agreed to by most physicists. But dielectric loss is probably connected in some way with dielectric absorption as Professor Whitehead has said, though the exact way, the mathematical formula by which it is connected, we do not yet know.

It is a very difficult question as to how to measure insulation resistance. Much of the work that is reported as measurement of insulation resistance is merely a measurement of some type of absorption. The last speaker did not say how he measured his insulation resistance but I am of the opinion that he did not measure what we may call the true resistance, but in some way he was measuring an absorption phenomenon, and he is showing by that exactly what Dr. Whitehead brought out, namely, there is a connection between dielectric absorption and power factor.

J. C. Lincoln: The point brought out by Dr. Whitehead that mica was not injured by the effects of ionization was new to me. The question I want to ask is this: I imagine that the reason for the destruction of fibrous material is the production of ozone and nitrous oxides from the ionization of the gas.

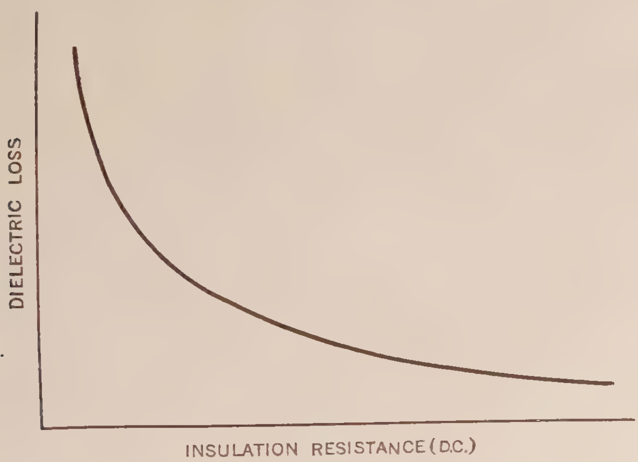

Fig. 1

I would like to know if that is the case, and also if these same materials, ozone and nitrous oxide, will affect such materails as rubber. I imagine they will, but are there other materials besides mica which are not affected by the production of ionization?

J. B. Whitehead: Several of the speakers beginning with Mr. Farmer have mentioned the power-factor curve as being perhaps the best method for determining the point at which losses begin. In the first section of my paper, presented at Swampscott, a number of power factor curves are given, and from the beginning we attempted to use the power factor curves as a means for detecting the point at which internal ionization begins.

In no single case did the power factor curve serve us in that connection. The power factor curves seem to run in a very erratic way, and show no marked breaks at the point at which the ionization sets in as determined by our own methods.

There was a definite break in the logarithmic curves and we have attributed this break to the beginning of ionization, particularly as pressure reduces the break in the curve.

It does not take a great deal of ionization to cause trouble. In the extreme cases we found the losses from ionization, those portions of the loss we could squeeze out of the sample, were relatively small. I have been wondering whether the ionization losses don't begin far down on the curve, but are still sufficiently small as not to reflect themselves very prominently. May we not have loss and still not yet reach a point where the cable is actually beginning to overheat, where the absorption itself and the major part of the dielectric loss which I take to be due to absorption, is not yet setting in in such a marked way that the cable itself is becoming unstable.

If you carry any of this insulation sufficiently high in voltage you get to a point where the loss is cumulative, not due to ionization, but due to the increasing temperature caused by the dielectric loss directly due to dielectric absorption.

It seems to me there is one other reason why we should not rely too much on power factor as a quantity for defining the ionization point. Power factor, after all, involves two quantities, the dielectric costant, of course, and such losses as are in the dielectric. Why try to tie those two things together when they certainly may vary, each of them independently of the other.

As regards the destructive effects: I have another paper which was published I think in the December number of the Journal which is a by-product of the work described in the present paper. The title of it is "The Influence of Gaseous Ionization on Fibrous Materials and Mica." The results are qualitative, but do show that gaseous ionization in very small amounts is quite sufficient to cause the most serious kind of deterioration of fibrous insulation of any kind within a few hours. Papers lose their calendered surfaces, lose their tensile strength. The whole mechanical structure of fibrous materials goes to pieces very soon, within the course of a few hours. We tried a number and none of them would stand up against ionization.

I think we also concluded very definitely that the most active agent was ozone. Nitrous oxides do not exist in air, in their own state, in any quantity, at least, at temperatures below several hundred degrees, so that it is fairly evident as shown in the paper referred to that the active agent is ozone. It is a slow oxidation, not rapid by any means. The results of this deterioration do not show up as ordinary combustion, as the blackening of the insulation. The deterioration seems to penetrate into the material in paths by some form of slow oxidation.

Mr. Lee pointed out in one case, at least, an armature bar having a very low dielectric loss was one of those to break down. That is perfectly true, but in the paper it is pointed out that the problem in applying mica in insulation of this character is largely one of uniformity and of being able to obtain a continuous product of high dielectric strength and good insulating properties uniformly through a course of continued factory production. So occasionally we unquestionably do find a bar well wrapped, in which the insulation is tight, and the internal ionization is low and which nevertheless fails. However, I think we reviewed a quite sufficiently large number of these bars to show that the one case of that kind that we found was simply fortuitous.

Mr. Del Mar has pointed out the importance of approaching this whole subject of insulation from a higher standpoint than we have done in the past and I simply want to call attention to the fact that the Engineering Committee of the National Research Council which is made up of our own research members, is attempting to take this higher viewpoint of the large mass of data that has been accumulated in this field of insulation. We are looking for assistance in carrying on that work, and if there are any here who themselves are interested, or know of others who are interested in the field of insulation, and are willing to take part in our present efforts of coordinating the results of the past, I would greatly appreciate it if they would communicate with me. We can give somebody a good, interesting and important job.

Mr. Alger, I think it was, pointed out his belief that the increase in the power factor is due to the boiling away of the material, the material of the binder. I don't know that I can make any comment on this except to point out that we have traced in

this paper a very direct relation between the ionization loss itself and the life of the bars. We find that a bar which has low ionization loss, when it is tightly wrapped, and in which it is impossible to squeeze out any ionization loss is the bar which goes on and shows the longest life and vice versa. Unquestionably the bars with the greatest amount of ionization loss in them immediately show a tendency to run down or break down.

Mr. Dawes' comments were really made principally on the other paper I have referred to, which was published in the JOURNAL and which we are not discussing here.

As regards the pressure: One of the speakers, Mr. Nyman, has asked what the pressure was that was used here, and raised the question as to whether all of the ionization loss was squeezed out. I quite agree with him that it is not all squeezed out, but we were able to squeeze it down to a point where the logarithmic loss is very straight. It did not seem to be worth while to attempt to measure the actual pressures that were used in this case. It was quite evident that this ionization loss must be very variable; it must be present in varying amounts, even in different parts of the same sample, and so the difficulty that would be encountered in measuring pressures, while one is also applying high voltage, led us to simply try to obtain approximately the same pressure for all these samples. That we did by constructing a special form of clamp in which the screws of this clamp were applied uniformly all over the surface and tightened up approximately to the same amount.

Mr. Halperin raises the question as to the $I^2 R$ square loss. $I^2 R$ loss as computed from the insulation resistance of the sample is unquestionably a very small part of the total loss. In that connection we can only consider the resistance as determined from the final value of the leakage current through the sample. If you apply continuous voltage, leave it long enough for the current to maintain a steady value, use that current as the basis of calculation of resistance, and then compute loss on the basis of that resistance, it will be found to be an extremely small part of the total observed loss.

As regards my comments in connection with insulation resistance, I mean to point out only that it seemed to me that it would be better if we used dielectric absorption itself as a means and a method of describing the material, rather than to speak of the insulation resistance. There is undoubtedly a very definite relation all the way through an experiment of this kind, between the value of the direct current which will be observed after one minute, and the alternating current dielectric losses which will be observed. In other words, as the resistance curves go up, indicating increased resistance, the loss curves come down, but the same thing would be found for a continuous curve measured at any other interval, whether one or two minutes, or one or two hours, and the connection is between absorption and loss and not between resistance and loss. I think it must be conceded unless there is some feature that hasn't come to my attention, that it is perfectly obvious that the great portion of loss of dielectric is due to the dielectric absorption and to nothing else.

OSCILLOGRAPHIC STUDY OF CURRENT AND VOLTAGE IN A PERMEAMETER CIRCUIT[1]

(KOUWENHOVEN AND BERRY)

PHILADELPHIA, PA., FEBRUARY 6, 1924

S. L. Gokhale (by letter): In this discussion I intend to limit my remarks to two points, namely:

(1) The choice of the ballistic galvanometer for permeametry.

(2) The use of shunts to control the currents in the several magnetizing coils of a permeameter.

These remarks have reference to findings No. 1 and 3 in the 'conclusions' of the paper under discussion.

In the history of the ballistic galvanometer there was at one time the belief, that a ballistic galvanometer should have little or no damping if it is intended to function properly as a ballistic galvanometer. It is beginning to be recognized now, that the relation of ballistic function to freedom from damping is purely accidental, and that an overdamped galvanometer is not only as good, but in fact much better than the undamped galvanometer for purpose of ballistic measurement.

A ballistic galvanometer is a galvanometer for measuring an electric impulse by transforming it into a mechanical momentum in the first place, and subsequently into a deflection, in which form the impulse is ultimately measured. The impulse under measurement is either directly a current impulse $\int$ idt, or a votlage impulse $\int$ edt (although this also is converted into a current impulse before it affects the galvanometer). In the first case the total impulse is expressed as a charge or quantity of electricity: $\int$ idt $= Q$. In the second case the impulse which is generated by change of magnetic interlinkage is expressed in terms of equivalent flux change, $\int$ edt $= n \, \Delta \, \phi$. A ballistic galvanometer used for measuring $\int$ idt or Q may be called a quantometer; when used for measuring $\int$ edt or $\Delta \, \phi$ it may be called a flux meter. The relation of Q to θ or of $\Delta \, \phi$ to θ, (where θ represents the deflection), expressed generally as a graph, is the calibration of the galvanometer. (The term quantometer, used in the sense of fluxmeter as I have defined fluxmeter above, was first used by Mr. R. Beṭtie in the *Electrician* Dec. 25, 1902, p. 383).

The calibration of a ballistic galvanometer, may be obtained either empirically by a direct measurement of a known impulse, or indirectly by mathematical computation based on dynamic principles. In the latter case, the necessary data to be used as a basis of computation is obtained by measurements with a steady direct current, of known amount. The legitimate use of the dynamic formula involves in theory the fulfillment of two conditions, (1) long period, and (2) no damping. From this point of view a ballistic galvanometer may be defined as a galvanometer of long period and little or no damping. The first condition was easy to fulfill and was little thought of. The ballistic galvanometer thus came to be defined merely as a galvanometer of little or no damping. It is so defined even now in college textbooks, and dictionaries.

But times have changed; ballistic galvanometers for magnetic measurements are now generally calibrated directly by measurement of a known flux or interlinkage. The calibrating standard (which is frequently a mutual inductor) has its secondary coil in series with the test coil and galvanometer. Under these circumstances damping has no influence on the final results.

On the contrary, damping has some decided advantages, particularly when the damping is electromagnetic and follows the law.

$$r = \; - \, c. \, d\theta \, / \, dt$$

i. e., the resistance to motion due to damping is proportional to the angular velocity.

When an impulse is made up of two equal and opposite impulses with an interval of time between them, the total impulse being zero, the resultant deflection ought to be zero also. Such a case arises in the Bureau of Standards method of measurement by the compensated double-yoke permeameter. With an undamped galvanometer, it is impossible to say when the flux in the various test coils is balanced. Users of the compensated double-yoke permeameter are therefore compelled to use some type of over-damped galvanometer; the Grassot's fluxmeter seems to be the most popular (A. I. E. E. 1915 p. 2602, Fig. 2 B) although I prefer a regular ballistic galvanometer with a high internal resistance in the form of active copper.

The superiority of the overdamped galvanometer over the underdamped, may best be demonstrated by the following experiment:—

A ballistic galvanometer practically undamped when used with a high resistance *Rg.* in series with it, is connected as shown in Fig. 1. The reversing switch is operated with the key down. The impulsive emf. produces a ballistic deflection. The key is

1. A. I. E. E. JOURNAL, Vol. XLII, December 1923, p. 1305.

then released; under the influence of the critical damping shunt, the galvanometer returns to zero and comes to rest, without any oscillations and with the least possible delay. The time taken up in the forward movement is ¼ of the complete free period. The time for return to zero is practically equal to the free period. During this time the reversing switch is generally brought back to the original normal position, so as to be ready for a second throw. The current is adjusted so as to produce a ballistic deflection of 100 mm.

The reversing switch is now operated forward and backward with the key down throughout the double operation. The final effect on the galvanometer ought to be zero; but the actual effect is positive or negative, large or small depending on the interval between the two reversals. It is never zero except by chance.

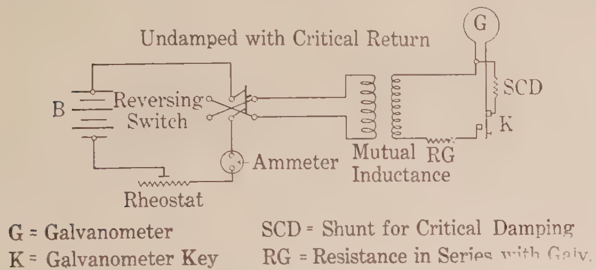

Fig. 1—Scheme of Wiring for Undamped and Overdamped Galvanometers

A low-resistance shunt Sg is now connected as shown in Fig. 2, reducing the resistance Rg until the deflection for the single reversal is 100 mm. as before. It will now be seen that the double reversal produces a double kick, the final result being a zero deflection as it ought to be. With a highly overdamped galvanometer the resultant deflection is zero even when the two reversals are separated by an interval of several seconds. Instead of the critical damping shunt, it is now the practice of our laboratory to use a zero-setting inductor Z (Fig. 3). Instead of waiting for the galvanometer to come to zero, the operator is then able to bring it to zero much more quickly and easily by turning the knob of the inductor.

As to the oscillographic study as a research by itself, Messrs. Kouwenhoven and Berry are entitled to credit for patience, and

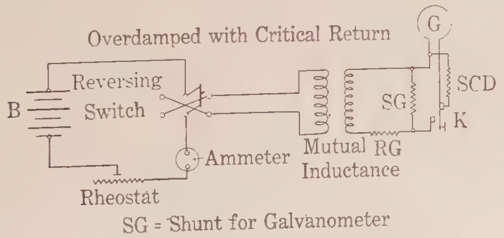

Fig. 2

care with which the work seems to have been done; so to the practical value of the research, I expect the contribution to prove of value somewhere, but I fail to see its usefulness in permeametry. For example, the authors have demonstrated the superiority of a laminated core over a solid core, in permitting the use of a short-period galvanometer (presumably undamped) in order to shorten the time spent in the test. This sort of solution ignores the nature of the problem.

The problem which confronts us in permeametry is not the choice of a test sample to suit our galvanometer, but the choice of a galvanometer to suit the sample. I had an occasion once, to measure the flux in the shaft of a turbo-generator. In such a case, a laminated sample for test is out of the question and one must choose his galvanometer to suit the material as it is. The research in question, was obviously undertaken with the behavior of undamped galvanometer in view. But as I said before, the times have changed. Twenty-two years ago Mr. R. Bettie demonstrated the possibilities of an overdamped galvanometer, and its immunity against errors due to slow or interrupted magnetic changes. (*Electrician*, Dec. 25, 1902, p. 383). In 1913 I had commenced an oscillographic study of the reversing switch, in connection with some difficulties I encountered in my experiments on the well known "Burrow's method," but the overdamped galvanometer seemed to be a complete solution of our difficulties and the oscillographic study was therefore discontinued.

It is true, that an overdamped galvanometer when deflected is very slow in coming back to its zero position; but one need not infer from this that such a galvanometer is slow for use, the fact being just the reverse. When a momentary impulse is applied, the overdamped galvanometer jumps almost instantly to the final position, where it stays long enough to take the reading conveniently; then it starts to creep back slowly, and would be several minutes in reaching zero if we had to depend entirely on its own free motion. It can however, be brought to zero very quickly by the zero setting inductor, or quicker still by reversing the first impulse when such reversal is possible and permissible, as it always is in permeametry. Consequently, the overdamped ballistic galvanometer is not only more accurate, but it is also easier to read and far more expeditious to use.

Messrs. Kouwenhoven and Berry have reached the conclusion that it is necessary to avoid a short-circuited path which is cut by the flux of a permeameter. This fact has long been known

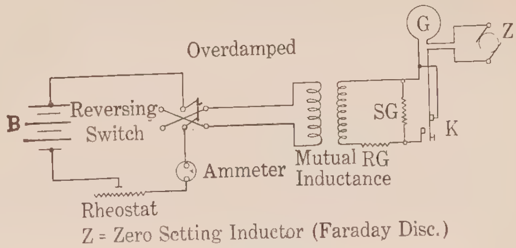

Fig. 3

and has long been recognized as a serious obstacle in the way of simplification of modern permeametry. In Burrows' permeameter there are several magnetizing coils which call for independent adjustment of current. Dr. Burrows has recommended the separate-circuit system with separate reversing switches. At first we followed this plan, using a long-period ballistic galvanometer without damping; but the balancing of the circuit proved an impossible task. We therefore abandoned the separate circuits and substituted for it a system of divided circuits such as was partly used by Dr. Burrows. This was a considerable improvement, but not enough. About this time I discovered, (what was already well known to others), that an overdamped galvanometer was the best remedy for the trouble. At this time I learned also, that with such a galvanometer, I could use separate circuits just as easily as the multiple circuit. But both methods had their advantages as well as disadvantages. The separate circuits involves the use of a gang switch, which becomes a very complicated affair when the measurement is extended to hysteresis. The divided-circuit system does not need a complicated gang switch so far as permeability measurements are concerned, but it is not available for hysteresis measurements. A third conceivable system is the series system in which the several magnetizing coils are connected in series, the necessary independent control being obtained by the use of separate shunts for the several coils, see Fig. 4. Here we meet the condition referred to by Messrs. Kouwenhoven and Berry. Such a system, if it were permissible, would simplify the work considerably; but is it permissible? It is possible that the shunt

would retard the change of flux in one coil much more than in the other. The difference of time might be so great as to make the balancing of the several circuits extremely difficult if not absolutely impossible. It is however possible to minimize the evil by the use of a self-compensating shunt, see Fig. 5. In this arrangement a part of the rheostat acts as a shunt and the other part as a self-compensating series resistance. The total re-

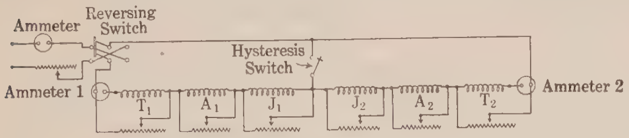

Fig. 4—Scheme of Wiring with Fractionizing Shunts (Uncompensated)

sistance of the local circuit is therefore high and remains constant, being unaffected by the setting of the shunt. This scheme of wiring has been incorporated in the permeameter equipment of the General Engineering Laboratory of the General Electric Co. and has proved very simple and expeditious. (See Fig. 6.) This diagram represents schematically the complete magnetizing circuit, omitting the auxiliary apparatus. Section 1 is used for permeability tests up to H 25, the coils T_1, A_1 and J_1, being the three magnetizing coils characteristic of the Bureau of Standards

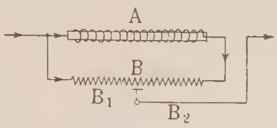

Fig. 5—Fractionizing Shunt (Self-Compensating)

A Magnetizing Coil
B Compensating Rheostat Shunt
B_1 Shunt Section
B_2 Compensating Section

method. Section 2 is an exact copy of Section 1, except that its polarity is reversed. Normally this section is cut out by means of the short circuiting switch "Hys.". When this switch is opened, the coils T_2, A_2 and J_2 become operative and the resulting value of H is less than that produced by section (1) alone. This gives a point on the hysteresis loop. Section 3 (not shown in the diagram) contained more layers of coils T and A which raises the magnetizing force to 200 gilberts in steps of 25

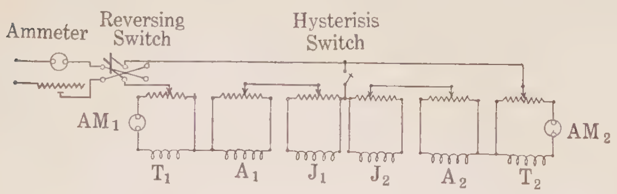

Fig. 6—Scheme of Wiring with Fractionizing Shunts (Self-Compensating)

gilberts or less as required. Tests for permeability are made by operation of the reversing switch alone, and for hysteresis, by the operation of the single switch "Hys". A complete discussion of the permeameter and the method of using it would be beyond the scope and purpose of this discussion. I have mentioned it here merely to show how by means of the self-compensated shunt, we avoided the difficulty referred to by Messrs. Kouwenhoven and Berry and at the same time eliminated the gang switch, which has always been since its invention, the dread of the operator who had the task of manipulating it.

W. B. Kouwenhoven: Mr. Gokhale's discussion of our paper and his description of the method he uses in operating the Burrow's Permeameter is of interest and value. Mr. Berry and I refer to an entirely different instrument, namely the Simplex Permeameter. This instrument is built with a U-shaped yoke usually of solid material. We found that better results could be more quickly obtained if the yoke were made of laminated material. Nothing was said regarding the use of laminated specimens. In our work an overdamped galvanometer was used when needed.

Mr. Gokhale states in his discussion that he fails to see the value of this paper, and in reply I will say, that, at the June Convention of the A. S. T. M., the engineers of two of our large electrical companies told me that they were now using laminated core simplex permeameters with excellent results.

EDDY CURRENT LOSSES IN ARMATURE CONDUCTORS [1] (Gilman)

Philadelphia, Pa., February 6, 1924

James Burke: With reference to Fig. 14 of the paper showing the offset segments, our company has used offset segments uniformly and continuously for 18 years in segmental punching machines and has not experienced any trouble from shaft currents.

P. L. Alger and R. F. Franklin: In view of the addition of Mr. Gilman's comprehensive papers to the already extensive literature on the eddy current losses in the conductors of large a-c. machines, it seems appropriate at this time to review the subject and describe the points of interest in the various articles from the point of view of a designing engineer. From this aspect, it is very desirable to be able to find in the shortest time and with the greatest accuracy and clearness what the eddy-current losses will be under any given conditions. Each of the articles that has appeared has features of particular value for the solution of certain problems, but most of them may be relatively inconvenient for use in the solution of any particular problem.

The first article to treat the subject in a comprehensive way was that by A. B. Field in the 1905 A. I. E. E. Proceedings. In this article, the physical phenomena of eddy currents are very neatly presented, accurate formulas starting with the classical differential equation are developed for most of the standard cases, and some interesting side-lights on the use of approximate formulas for the losses and on the calculation of reactance are given. This article may still be regarded as the best comprehensive review of the whole subject, considering synchronous machines, induction motors, and d-c. apparatus.

Mr. Gilman's article in the 1920 A. I. E. E. Proceedings treats the subject of large synchronous machines in much greater detail than Field's article. In it are derived accurate formulas starting with the classical differential equation for the eddy losses in special cases not considered by Field, such as the carrying of a single strand through the whole phase belt before clipping it to the other strands of the same conductor. The alternator designer will find in this article formulas for all windings in use at the present time except those in which twisted conductors are employed. However, Mr. Gilman does not preserve the physical view of the phenomena while carrying out the solution of the equations, which is so necessary to a clear understanding of the effects of changes in conditions from those directly considered.

Mr. W. H. Taylor has published an extremely interesting article on the subject in the Journal of the I. E. E. for April, 1920. He goes to the other extreme from Mr. Gilman by beginning with the physical viewpoint and building up the losses as a result of the summation of the effects of component eddy currents due to each conductor separately. In this way he derives

1. A. I. E. E. Journal, Vol. XIII, March, p. 194.

formulas in the form of infinite series, in which only the first term is ordinarily used. However, the accuracy of these formulas is entirely sufficient in all cases of alternator windings in which the losses are not so excessive as to be unreasonable. Taylor treats all the standard cases of alternator windings and several curious cases in addition. For example, he shows that a coil that is turned over at the connection end but is wound straight up at the other end would have a very small loss, if such a coil were mechanically feasible to make. On the whole, I believe that Taylor's article is the best from the point of view of the designer of synchronous machines, as his formulas are the simplest (they require no curves or tables) and his presentation renders it easy to see the effects of whatever changes in the winding the designer may be able to imagine. Taylor also does not consider the twisted conductor of the Roebol type although he does treat the conductor that is turned over in the middle of the slot.

The twisted conductor has been considered at some length by German and French writers. For example, Fleishmann has shown that the circulating-current loss in a conductor will be completely eliminated if every strand in it has the same r. m. s. height in the slot. However, the use of such twisted conductors requires that they be clipped at each end, and so precludes the use of a machine-wound coil. For this reason, as well as because the labor in making them is greatly in excess of that for a normal conductor and the space factor of the slots is reduced by their use, they have not been adopted in this country. Therefore, most of the continental literature on the question is of relatively little interest to American designers.

The induction-motor designer is also interested in the question of eddy-current losses, since it is possible by exaggerating the eddy currents in the squirrel cage to obtain a greater starting torque per kv-a. than in the ordinary motor. Here, however, the losses are purposely made as large as possible, and so they fall outside the range of accuracy of Taylor's formulas. Also the feasible types of conductor are widely different from those used in alternators which are discussed by Taylor and Gilman. Finally, it is necessary in this case to consider the reactance as well as the resistance, and none of the articles so far mentioned gives any adequate method for calculating the reactance. For these reasons I believe the induction-motor designer had best put all his energy into the study of the article by Prof. W. V. Lyon, in the 1922 A. I. E. E. PROCEEDINGS.

This article treats the whole subject of eddy currents by the vector method used by Kennelly and others in the solution of transmission-line problems. By this method the vector impedance of a conductor carrying alternating current is carried through the whole series of equations and found numerically, as a ratio to the d-c. resistance. This contrasts with the method followed by all the other writers in which the losses are separated from the reactive power at as early a stage as possible and thereafter they only are considered. While Lyon's article does not give numerical results directly usable by the designer, he does give methods and formulas which with a little further work can be put in a form to give accurate and complete values for the effective impedances of all kinds of squirrel-cage conductors. Thus this article is the most basic and comprehensive for use as the foundation of future work on the subject.

M. S. Vallarta: In a discussion on a paper by W. V. Lyon,[1] I presented certain results of an experimental investigation undertaken in the Research Division of the Electrical Engineering Department, Massachusetts Institute of Technology, the purpose of which was to test the correctness of the premises on which Field's[2] one-dimensional theory of skin-effect in armature conductors is built up. As all resistance-ratio formulas given in the paper under discussion are based on this theory, a reexamination of its underlying assumptions in the light of recent developments does not appear superfluous.

Perhaps the most fundamental and least evident of these assumptions is that the component of magnetic field strength parallel to the slot side vanishes everywhere within the cross-section of the conductor. In view of its importance, especial efforts were made in the course of the investigation already referred to in order to bring to light conclusive experimental evidence on this point, but in spite of them, the conclusion, stated in 1922, was: "No satisfactory proof of Field's assumption of no component of field strength parallel to the slot side has been found."[3] Unexplained discrepancies, ranging from 2 to 5 per cent, were observed between calculated and measured resistance-ratios. Such discrepancies were believed to be due to the fact that the current density is not actually constant along planes parallel to the slot bottom, *i. e.*, that skin effect is not one-dimensional. The purpose of these lines is to show how far this two-dimensional skin effect may be expected to come into play and how it affects resistance-ratio formulas.

In a recent paper, Steidinger[4] has examined the problem for the case of a *single massive* conductor which does not completely fill the slot and given formulas for the Joule loss. We consider a single massive rectangular conductor of width $2b$ and height $2a$ embedded in a rectangular slot of width $2B$ and height $2A$ (Fig. 1). On its cross-section the current distribution is a

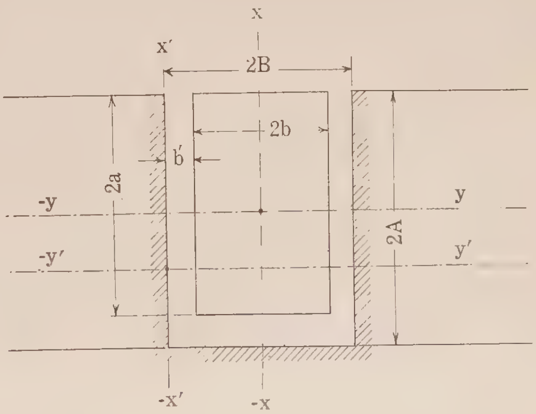

FIG. 1

function of x and y, that is, Field's assumption of one-dimensional skin effect, in which the current density is a function of x only (x = distance of current element from bottom of slot), is given up. The time variation of all electromagnetic quantities is assumed to be monoperiodic, as is done in Field's theory and elsewhere in the literature. We therefore write:

$$c = u(x, y) e^{j \omega t}$$

where c is the current density at a point $(x\, y)$ and ω is the circular frequency of this current. $u\,(x\, y)$ is determined by Maxwell's circuital equations:

$$\Delta \times H = \frac{4\pi}{c}\left(\sigma E + \frac{\epsilon}{4\pi}\frac{\partial E}{\partial t}\right),$$

$$\Delta \times E = -\frac{\mu}{c}\frac{\partial H}{\partial t}$$

with $\quad \Delta \,.\, H = 0 \qquad \epsilon\, \Delta \,.\, E = 4\pi\rho$

where H and E are the magnetic and electric field strengths, σ, ϵ, μ, the conductivity, permittivity and permeability, c is the velocity of light in free space, ρ the space electrical density, all expressed in absolute (Gaussian) units; and $\Delta\, x$, Δ. denote the operator's curl and divergence, in Gibbs' notation. Since skin

1. W. V. Lyon, "Heat Losses in Stranded Armature Conductors," TRANS. A. I. E. E., Vol. 41, p. 199, 1922.
2. TRANS. A. I. E. E., Vol. 24, p. 761, 1905.
3. TRANS. A. I. E. E., Vol. 41, p. 212, 1922.
4. *Archiv. fur Elektrotechnik*, Vol. 12, p. 149, 1923.

effect is assumed to be two-dimensional, $\frac{\partial}{\partial z}$ is an annihilator and the electric and magnetic field-strength components satisfy the equation—derived by curling from the two circuital equations:

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = j \frac{4 \pi \sigma \mu \omega}{c} u - \omega^2 \frac{\epsilon \mu}{c^2} u$$

but, since in a metal the displacement current $\frac{\epsilon}{4 \pi} \frac{\partial E}{\partial t}$ is negligible compared with the conduction current, this reduces to:

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = j \alpha^2 u \text{ with } \alpha^2 = \frac{4 \pi \sigma \mu \omega}{c}$$

Field's[5] equation is obtained from this, provided the conductor completely fills the slot, by simply noticing that for one-dimensional skin effect $\frac{\partial}{\partial y} = 0$ and that in electromagnetic units $c = 1$.

A particular solution of this last equation is:

$$u(x, y) = C \cosh [x \sqrt{n^2 + j \alpha^2 + \beta}] \cos (n y + \gamma)$$

where C, n, β, γ are arbitrary constants, which may be complex numbers. By symmetry $u(+y) = u(-y)$, so $\gamma = 0$. n is determined by the condition equation obtained from the boundary conditions—continuity of the magnetic field—upon the plans $y = -b$ $y' = b'$

$$n \tan (n b) + \sqrt{n^2 + j (\alpha^2 + \beta^2)} \tan [b' \sqrt{n^2 + j (\alpha^2 + \beta^2)}] = 0$$

where b' is the distance from slot side to conductor, (see Fig. 1). This equation has an infinite number of complex roots n_k.

Likewise, the constant β is determined by the boundary conditions at the top and bottom. There is a difficulty here because the boundary conditions at the top of the conductor are not definitely known. In an alternator, they would depend on the relative position of the slot with respect to the pole face. If we write the solution in the form:

$$C = A e^{j \omega t} \sum_{k=1}^{\infty} C_k \cosh [x \sqrt{n_k^2 + j \alpha^2}] \cos (n_k y)$$

there is another difficulty because the normal solutions are not orthogonal and hence the coefficients C_k cannot be determined by Fourier's method. We shall not go into this here, but refer to Steidinger's paper (l. c. p. 152) for details. In what follows, the argument is limited to the fundamental harmonic ($k = 1$).

Assume that the conductor carries a total current $\sqrt{2} I e^{j \omega t}$. The average over a cycle of the total heat loss in the conductor is

$$\bar{Q} = \tfrac{1}{2} \int \rho / c /^2 d v$$

ρ being the resistivity ($\rho = 1/\sigma$) and the integral being taken through the volume of the conductor. Integrating, and again referring to Steidinger's paper for details, we get:

$$Q = R I^2 \left[m_1 a \frac{\sinh 2 m_1 a + \sin 2 m_1 a}{\cosh 2 m_1 a - \cos 2 m_1 a} \right]$$

$$\left[m_2 b \frac{\sinh 2 m_2 b + \sin 2 m_2 b}{\cosh 2 m_2 b - \cos 2 m_2 b} \right] \qquad (1)$$

where R is the ohmic resistance, $m_1 = \alpha \sqrt{b/B}$ and $m_2 = \alpha \sqrt{b'/B}$. The resistance ratio K is $Q/R I^2$ by definition.

The function in parentheses is always greater than unity except for argument zero, when it becomes unity; it has been tabulated and plotted.[6] It is *only when the conductor completely fills the slot* ($b' = 0$) that the above equation reduces to Field's corresponding formula, which is derived also by Gilman, Lyon and others. It is only in this case that the resistance ratio, calculated by using one-dimensional skin-effect formulas, such as those given by Rogowski, Gilman, Lyon and others[7] can be expected to agree with facts. This conclusion is wholly in accordance with experimental evidence available to date.

In all practical cases, where the conductors do not completely fill the slot, the resistance ratio is *greater* than that calculated from one-dimensional formulas, such as given by Mr. Gilman in the paper under discussion. That the two-dimensional correction is usually negligible, but may easily become important is perhaps best shown by two illustrative examples.

As a first instance, take the test coil used in our M. I. T. investigation. Its dimensions, assuming a massive conductor, are, $2 b = 1.418$ cm., $2 a = 3.58$ cm. The slot dimensions are, $2 B = 1.905$ cm., $2 A = 7.62$ cm. The conductor is assumed to be laid flat on the slot bottom, symmetrically with respect to its sides. Then $b' = 0.24$ cm., and from the above formulas, $\alpha = 1.671$ cm.$^{-1}$ at 60 cycles for commercial copper and $m_2 = 0.861$ cm.$^{-1}$. The correction due to two-dimensional skin effect [2nd parenthesis in formula (1)] is 1.03 approximately, whereas the measured value was 1.02. Too much worth cannot be attached to this check, first, on account of the special construction of the coil which largely eliminated two-dimensional skin effect, second, in view of the uncertainty in the elimination of the iron loss, and third in view of the smallness of the correction.

As a second example, take the generator quoted in Gilman's paper under discussion. Here $2 B = 1$ inch, $2 b = 0.5$ inch. So $b' = 0.634$ cm. and $m_2 = 1.182$ cm.$^{-1}$. The two-dimensional correction is here about 1.12.

It should be carefully emphasized that the resistance-ratio formula (1) takes into account the fundamental harmonic only and that the two-dimensional skin-effect theory of n conductors per slot has not yet been worked out. In this sense, the above examples are only illustrative. Judging from available experimental evidence, two-dimensional skin effect seems to be more effective for conductors near the top than for those near the bottom. It follows that care and judgment should be exercised by the designing engineer in the use of Gilman's formula, particularly in the case of wide slots and highly insulated conductors.

R. B. Williamson: About 17 years ago the subject of eddy-current losses in armature conductors was brought before the Institute in a paper by A. B. Field. Previous to this it was known in a general way that generators sometimes developed high temperatures in the windings for no well explained reason. Such temperatures were not due to lack of sufficient copper, because the apparent current density in the copper was in many of these cases quite low. Mr. Field's paper showed that the excess heating was due to eddy currents and gave means for estimating the amount of such excess loss. This paper, however, gave the methods of estimating the loss for solid conductors only, or for those infinitely laminated. In windings as actually made, the lamination can only be partial, and Mr. Gilman's previous paper presented before the Institute carried Mr. Field's work further and showed how to estimate the eddy current loss for different arrangements of winding and various degrees of stranding of the conductor. The present paper takes up some additional cases not covered by the previous one, and the two papers taken together form a very complete treatment of the whole subject. It is not possible to build successful large generators without taking this eddy-current effect carefully into account and arranging the winding accordingly. Contributions such as these by Mr. Gilman, while on the face appearing highly theoretical, are of the greatest practical

5. This equation is also the starting point of Lyon's and Gilman's papers.

6. For instance by W. Rogowski in *Archiv fur Elektrotechnik*, Vol. 2, p. 97, 1913, also by W. V. Lyon, TRANS. A. I. E. E., Vol. 40, p. 1361, 1921 (Fig. 3). Notice that our m_1 is Gilman's "α" or $1/\sqrt{2 j}$ Lyon s "α."

7. For instance Emde, *Elektrotechnik und Maschinenbau*, Vol. 40, p. 301, 1922. Also, Mayer, *Archiv. fur Elektrotechnik*, Vol. 12, p. 349, 1923.

importance to the designer and will doubtless form a valuable reference on this subject for many years to come.

S. L. Henderson: I think it has been pretty well brought out today that Mr. Field's article on eddy currents covered only two cases of conductors, namely, that of the solid conductor and that of the infinitely stranded conductor; obviously, only one practical case—the solid conductor.

I happened to be associated with Mr. Gilman at the time he developed an eddy-current formula and assisted him with the tests for checking the results of this formula, and while I am not entirely familiar with Mr. Taylor's article or with the discussion of Mr. Vallarta on whether the case comes under the one-dimensional or the two-dimensional theory, this much I do know: That the tests we made checked within one per cent of our calculation, and it is obvious, therefore, that in view of the other features of design which are not accurately determinable, any formula that will give results within one per cent is acceptable.

The comment was also made that Mr. Gilman's formula appeared involved and required considerable effort to apply. Of course, my point of view may be warped inasmuch as I have been using this formula probably for four or five years, but with the formula and the curves I think it is possible to check the eddy-current loss in any armature conductor within ten minutes; probably five minutes in the average case.

I think there was also a statement made that Field's article would cover most of the cases. This might be true on small machines, but where the size gets beyond, say, 1000 or 2000 kv-a., the conductors are stranded either twice or more times, and consequently it is necessary to be able to calculate the amount of eddy-current loss in the conductor, and it is only possible to do this with the aid of the formula as worked out by Mr. Gilman or possibly as stated by Mr. Taylor or Professor Lyon.

METHODS OF TESTING CURRENT TRANSFORMERS[1]

(Silsbee)

Philadelphia, Pa., February 7, 1924

I. M. Stein (Philadelphia): On the first and second pages of Dr. Silsbee's paper, a figure of 0.3 per cent is given, as being a maximum for the ratio error in "loop-through" types of current transformers. A number of people are using this type of transformer for standards, and accordingly, the figure given is of particular interest.

We know that there is a difference in the construction of transformers of the "loop-through" type, some being very poor and some very good, a great deal depending upon the way the secondary winding is distributed around the core, and something depending upon whether there are any joints in the laminated core.

If the figure is a maximum for the poorest type, there is not so much to worry about. If it is the figure representing the variations which may be expected in the best type, then it would seem a rather large error for a standard, and I should like to learn from Dr. Silsbee whether the best transformers of that type show errors as large as 0.3 per cent.

Referring now to the vibration galvanometer—the paper indicates in two places that the vibration galvanometer is a delicate instrument.

It is probably true that a number of vibration galvanometers are very delicate, particularly if made to cover a very wide range of frequencies, and perhaps if made considerably more sensitive than is necessary for ordinary measurements on current transformers.

I am familiar with vibration galvanometers that are extremely rugged in construction. They are more rugged than the galvanometer that is used in portable testing sets, the suspension being about twenty-five times as strong as those of the portable galvanometer. I don't think Dr. Silsbee meant to indicate any delicate construction in the vibration galvanometer. I should like to know what interpretation should be placed on his referring to the vibration galvanometer as a delicate instrument.

In connection with the absolute-resistance method, the paper states that precautions must be taken to avoid errors due to capacity current which may circulate through the detector from the primary source of current. The precaution applies to tests

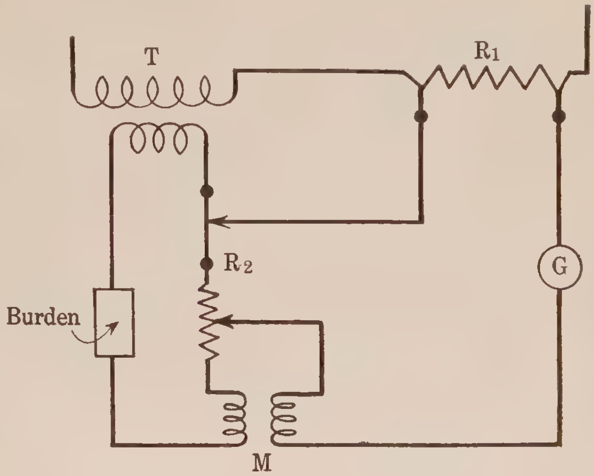

Fig. 1

where you have a sensitive detector, which will pick up very small leakage currents.

The thought occurs to me that if we have leakage in testing where we are using a fairly low voltage for supplying the transformer under test, we must have some leakage when the transformer is installed on a very high-voltage line, say 50,000 volts. Is there any capacity current there which will affect the accuracy of the transformer, particularly at light loads?

I appreciate that the instruments used in service are far less

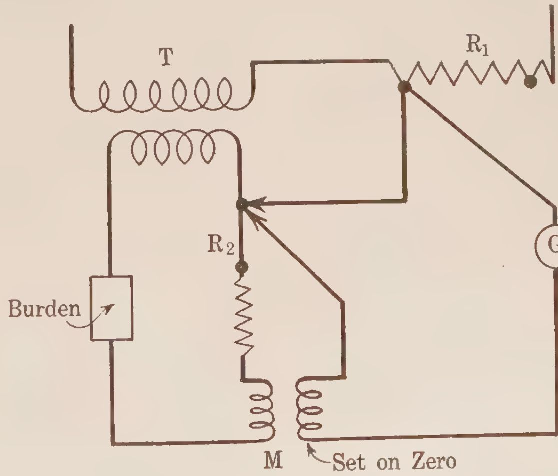

Fig. 2

sensitive than those used in testing, but I haven't seen any figures or heard of any results of measurements made to show the probable magnitude of the error.

I should like to add another precaution in dealing with heavy current and sensitive detectors—I refer to stray fields. I think that anyone who has worked with instruments of the kind mentioned, or circuits of the kind mentioned, knows that the effects of stray fields must be eliminated before accurate measurements

1. A. I. E. E. Journal, Vol. XLIII, March, p. 239.

can be made. In eliminating stray fields, I should like to put in a good word for the vibration galvanometer, when used with the circuit Dr. Silsbee has shown.

In Fig. 1, shown herewith, T is the current transformer being tested, R_1 the primary non-inductive resistance, R_2 is the secondary non-inductive resistance, and M is the mutual inductance. As R_1 and R_2 are made up, the terminals are very close together, and the leads all need to be twisted together to avoid picking up stray fields. The inductance is made astatic, but it may be somewhat affected by stray fields.

If the two leads at R_1 are put under the same binding post (Fig. 2) and the same thing is done at R_2, it involves only a very slight movement, because the binding posts are very close together. If now the mutual inductance is set to zero, then with the full primary current going through the circuit, there should be no vibration of the detector. The circuits must be so arranged to avoid any deflection of the galvanometer under these conditions before you can start to test.

The vibration galvanometer is an excellent detector for this work because as Dr. Silsbee has said, it responds to any current of the fundamental frequency regardless of the phase of that current. You can do a similar thing with a detector requiring shifting the phase of the field current, but that is not so easy, and the very motion of the phase shifter may influence the detector and cause trouble. The vibration galvanometer is an excellent exploring device for getting rid of stray-field errors before starting the measurements.

W. H. Pratt: There is just one word of caution that I think it is well to express; that is, that we should not in practical testing expect from the more convenient methods of relative testing an accuracy approaching the accuracy that can be obtained by the more exact methods. That is I think clearly pointed out in Dr. Silsbee's paper, but nevertheless the figures that sometimes appear as representing what can be obtained by the convenient methods, are a little bit dangerous; that is, they are a little bit better, perhaps considerably better, than are often obtained in the hands of many who may be expected to use these methods.

Frank V. Magalhaes: I would be glad to offer a constructive suggestion to the author of the paper. It would have been very desirable to have Dr. Silsbee add or consider the factor of time as well as the order of accuracy involved in the use of the various equipments and methods. For example, it might be understood that the methods which Dr. Silsbee calls the balanced absolute methods and which employ equipments more or less elaborate would also take considerable time to obtain the measurements. This is not so. With a properly designed primary equipment and a trained operator it is possible to obtain within a few minutes the precise readings of ratio and phase angle which Dr. Silsbee describes in detail.

Dr. Silsbee's paper is a very well prepared comparison of the accuracy of the results that may be obtained by the different equipments or the different methods. There are, however, other factors which would affect the decision of any individual or organization which might be considering the purchase of such a checking equipment for instrument transformers.

The public utilities are probably the largest class of users of instrument transformers in the country. These transformers are used either in connection with the watthour meters or with the power relays, both requiring accurate adjustment.

The various utilities operate under varying rules, depending on the locality. These rules may be the State Public Service orders or municipal regulations in connection with the accuracy and periodicity of check of watthour meters. Certain of these rules require periodic checks of the instrument transformers. These tests may be made on the transformers as received new and prior to installation or may be made in position and connected in service.

Careful consideration would need to be made of various factors, such as the number of transformers involved, the cost of removing them from service for possible check, the period of time between checks and the degree of accuracy desired on the check itself to enable decision to be made as to the type of equipment to be purchased and used.

If the measurements were to be made only on new transformers as received from the manufacturer and they were received in sufficient quantity, these conditions would justify the purchase of one of the more elaborate or expensive equipments, giving balanced absolute results which are of a high order of accuracy and can be very quickly obtained.

If, however, the equipment is required for a public utility of relatively small size with a limited number of instrument transformers all in use and these are by local rule subject to a short period between tests, it would probably be cheaper not to remove the transformer from service but to purchase and use one of the portable sets that do not give the precise results of the laboratory equipment, but provide sufficiently accurate results for the purpose and could be used to test the transformers in position.

One other point that I believe might have been discussed or emphasized by Dr. Silsbee and that is the number of operators necessary to use the various equipments.

It might be considered that the more elaborate equipments giving the precise readings would require several operators. This is not so as equipments of this character can, after they are set up and properly calibrated, be operated very satisfactorily and quickly by a single well trained operator.

J. R. Craighead (Schenectady): There is in Dr. Silsbee's paper, I think, a little tendency to confuse the sensitivity of a method with the accuracy obtainable from the method.

Without going into the details of the methods presented I wish to suggest that the reader keep in mind that the sensitivity which a method will produce is a distinct thing from the accuracy and that the sensitivity mentioned in certain of these cases should not be read as accuracy because the accuracy of the method is dependent upon the certainty of calibrations of the various parts of the apparatus, the accuracy of adjustments, the certainty of temperatures and many other things while the sensitivity is dependent only on the theory of the method, and the relation of the quantities selected for comparison to the sensitivity of the detector.

Perry A. Borden (by letter): The only one of the methods described by Mr. Silsbee for testing current transformers, with which I can claim to have had any great experience, is the Baker Test Ring; but since this combines the precision of an absolute method with the convenience and simplicity of a relative method, I trust I may be pardoned the seeming narrowness of my viewpoint. For fourteen years I have found this system most satisfactory for all classes of current transformers, whether in the laboratory, the workshop or the field. Even with the roughest readings an accuracy of 0.1 per cent is obtained; and with reasonable care ten times that degree of precision may be expected. An excellent dynamometer for use with the ring consists of a Weston Model 310 "low-power-factor" wattmeter, with its moving coil fed directly from the fine wire winding on the ring, and its field excited from normal load current, taken alternately from two phases of a three-phase system. (Higher precision could be obtained with an instrument of the zero-reading type, which would obviate mutual inductance between internal circuits).

In actual practise it is usual to take three or more readings at each value of current, when the system becomes self checking; for, if any source of error has intruded itself into the observations it is almost certain that the several points as plotted will depart from their ideal condition of even spacing along a straight line. For general work it has been found practicable to plot the read-

ings on isometric paper, thus doing away with the need for a drawing board and special scales; and under these conditions the computation becomes very simple, and the possibility of error practically nil.

The true secondary burden on a current transformer interconnected with others on a polyphase metering system is almost impossible to duplicate in the laboratory; and the constants of transformers so installed will differ according to whether they be installed on the leading or the lagging phase of the system. It is highly desirable, therefore, that where the measurement of large blocks of power is concerned, the transformers be checked under actual operating conditions. The Baker method lends itself particularly to work of this class; for, while the outfit is easily portable, the possibility of completely insulating the primary from the secondary winding makes it possible to connect the apparatus directly into the feeder under test, and obtain an absolute determination of current-transformer constants with the circuit actually carrying its load. This, I believe to be regular practise in the plant of the Ontario Power Company at Niagara Falls.

F. B. Silsbee: Mr. Stein asked if this figure of 0.3 per cent possible variation in the pole-type transformer would be applicable to other than bad ones. I think the answer is that it is only in the poorer types of transformers that a variation of this magnitude can be expected to result from different locations of the primary cable. We have made tests at various times at the Bureau on pole-type transformers, trying to place the leads through the holes, in the most widely different positions. In the worst transformers we have come across, have had as much as a 0.5 per cent difference. In the better grades, where the winding is distributed, the error to be expected is decidedly less than the figure in the paper. I put this figure in merely as a caution.

In the matter of capacity currents in the transformer, that is a very interesting point, and I don't think any one knows the answer definitely. Of course, in testing the transformer, especially by the absolutely balance methods, instruments are used which are much more sensitive than the ammeter and wattmeter used in the transformer service. In the higher voltage ranges it is barely possible such a variation would come in.

Stray fields are one of the things always found around heavy current set-ups, and I thought that stray field precautions were so axiomatic they need not be mentioned. The way Mr. Stein outlined is the handiest way to test for stray fields, and is the way we have been doing it at the Bureau.

Mr. Magalhaes raises the question of time. One reason for not laying more stress on it in the paper is the difficulty of estimating the time it takes for a given job because this time depends so greatly on the skill of the operator. Another point is that in most cases a large fraction of the total time of the test is employed in making the connections and in adjusting the burden to properly duplicate the burden at which a test is to be made. All of this time is an overhead common to all methods. After this time is allowed for there is little difference between them as Mr. Magalhaes has pointed out for the balanced method. With the two watthourmeter methods you have to take time to let the meters grind out a fair number of revolutions and this time is considerable, and is referred to in the paper. Practically all of the methods can be worked with one observer, although it is often convenient to have two men on the job.

Mr. Craighead's comments on the difference between sensitivity and accuracy are well taken. One of the fundamental things to care for in all of this work is to have the burden on the transformer correspond to that at which the standard transformer was tested, and to that at which the transformer under tests is to be used. Any departure from this introduces an error quite apart from the sensitivity of the method and must be guarded against.

TOOTH PULSATIONS IN ROTATING MACHINES[1]
(Spooner) and
SURFACE IRON LOSSES WITH REFERENCE TO LAMINATED MATERIALS
(Spooner and Kinnard)

Philadelphia, Pa., February 6, 1924

G. E. Luke: These two papers on iron losses are very worthy papers in that their purpose is to give the designing engineers a knowledge of the stray losses which occur in a machine. These stray losses are very large in the case of some induction motors and in the case of turbo-generator and other high speed electric machines. The old d-c. machines had solid pole faces; the losses on those were large. The only thing that limited them and kept them down within reasonable value was the fact that they used large air gaps. But as the designs were improved, the air-gap was brought down, particularly with the use of the commutating pole, and it was necessary to reduce these pole-face losses; this necessitated a laminated structure.

These papers give a valuation of those losses and how they can be reduced by changing the size of the laminations or by insulating the laminations in the pole. The tooth-pulsation losses are of especial importance because they occur in the tooth zone where the losses are the greatest, due to the copper loss and the high densities found there, and they may be appreciable; sometimes larger than the fundamental loss.

These losses are important first, as regards efficiency; probably of greater importance, though, with regard to heating of the machine. In other words, they limit very seriously the output of the machine as far as temperatures go, and if we can evaluate those losses, it will give the designing engineer a better idea of what his machine will do. In mechanical engineering we have a figure which we call "factor of safety;" it might be called "Factor of ignorance" because it is a figure which takes into account imperfections in design or material.

In electrical engineering we have a similar figure which we use in the magnetic circuit. We obtain losses on the raw material and multiply by that factor, which takes into account the stray losses, and if we can reduce that factor we will put the design on a higher plane and be able to predetermine the performance of any machine to a higher degree of accuracy.

P. L. Alger: I wish to comment on Messrs. Spooner's and Kinnard's paper on surface losses, making two points particularly. One point concerns the relation of the paper to the previous art; and the second concerns the application of the dimensional theory to the results of the paper.

Articles have been published in recent years giving methods for calculating the line-frequency losses and demonstrating their practical accuracy. Mr. Spooner's article now gives us methods for calculating surface losses with reasonable accuracy. Recent papers by Rosenburg and others have given methods for calculating the losses in the adjacent metal parts. These three types of loss, together with the pulsation losses, make up practically the whole core loss of commercial machines. Therefore, if we may hope to have a paper upon pulsation losses, as good as Messrs. Spooner's and Kinnard's paper on surface losses, in the near future, we ought to be able to calculate core losses with satisfactory accuracy. I hope such a paper will be forthcoming before long.

The second point I wish to make is that if you make use of the dimensional theory (which states that the quantity measured is not be affected by any change in the units employed), by applying it to Messrs. Spooner's and Kinnard's results, you may derive some rather interesting conclusions. They find, for example, that the total loss varies approximately as the 2.5 power of the density, when the different exponents for the different conditions are averaged. If this is so and if it is assumed that in calculating these losses theoretically the

1. A. I. E. E. Journal, Vol. XLIII, July, p. 646.

only factors to be considered in addition to those which they have varied are the resistivity, the thickness of the laminations, and the saturation value of density, then it must follow from the dimensional theory that the loss will vary as the minus 0.5 power, or the inverse square root, of the saturation value of density. Thus we have a measure of the gain it is possible to make by changing the saturation value of the density. Similarly, assuming their exponents to be correct for the variation of the loss with the frequency and with the tooth pitch, it follows that the loss should vary approximately as the minus 1.5 power of the resistivity. The ordinary theory, based upon a constant permeability shows an exponent for the resistivity of minus 0.5. This variation as the minus 1.5 power makes the resistivity very much more important in reducing the losses than we would expect from the conventional theory.

Finally, it may be shown that the losses must vary about as the 1.7 power of the lamination thickness, if the exponents derived for the other variables are really true. Since their tests on variations in lamination thickness show the square law to hold at low thicknesses and the first power law to hold at greater thicknesses, it also follows that their exponents for density and tooth pitch cannot be true over the whole range.

In brief, the whole range of their experiments may be coordinated, made more reasonable, and extended by applying the dimensional theory to their results.

I have prepared a table of the exponents derived in this manner which gives the values expected for the several cases.

TABLE OF EXPONENTS

Experimental					Deduced		
Material	B_{AG}	f	λ	q	B_{SAT}	ρ	t
.0172 M. A.	2.2	1.7	1.1	1.7	− .2	−1.3	1.9
.0281 Bessemer......	2.4	1.6	1.3	2.15	− .4	−1.4	1.7
.0625 "	2.6	1.6	1.3	2.2	− .6	−1.4	1.7
.125 "	3.1	1.6	1.3	2.3	−1.1	−1.4	1.7
Solid Steel*	2.5	1.5	..	1.4	− .5	−1.5	..
.0172 M. A. .... (Induction Motor)	1.9	1.55	..	..	0.1	−1.45	..

*Taken for unpublished experiments. The other figures are from tables *C* and *E* in Messrs. Spooner and Kinnard's paper.

I. F. Kinnard: In closing this paper, I have no further remarks to make, excepting to explain in a little more detail Fig. 11 on page 9. You will note that this is a comparison between the losses obtained, using chamfered poles and ordinary poles with a uniform gap. The basis of the comparison was using minimum air gap; that is, in the case of the chamfered poles we used minimum air gap at the center and average induction. The reason for this I think I can make clear:

Assume a uniform air gap, and a non-uniform gap due to chamfered poles. For the reason that in both cases, we are using average air gap induction over the entire pole face, it is easy to see that in the case of the chamfered poles the losses are increased somewhat due to the greater flux density at the center. These higher losses are satisfactorily accounted for, if, instead of using average length of gap in our formulas, we use the minimum gap in all cases.

Although this is an approximation, it is sufficiently accurate for practical purposes.

In closing this paper, I have no further remarks to make, excepting to explain in a little more detail this Fig. 11 on page 9. You will note that this is a comparison between the losses obtained, using chamfered poles and ordinary poles with a uniform gap. The basis of this comparison was using minimum air gap; that is, in the case of the chamfered poles we used minimum air gap at the center and average induction. The reason for this I think I can make clear.

T. Spooner: I would like to say a word in regard to the practical effect of saturation on tooth pulsation losses. In the paper we did not mention losses specifically but this investigation was made, of course, with the definite purpose of applying the results to the calculation of losses. Suppose we plot from experimental results tooth pulsation losses against air gap induction, we shall obtain a curve similar to Fig. 1. If there were no tooth saturation, the curve would continue as shown by the dotted line but due to the reduction of tooth pulsations caused by saturation, the rate of increase of loss decreases and if the induction were carried high enough, the losses may actually decrease.

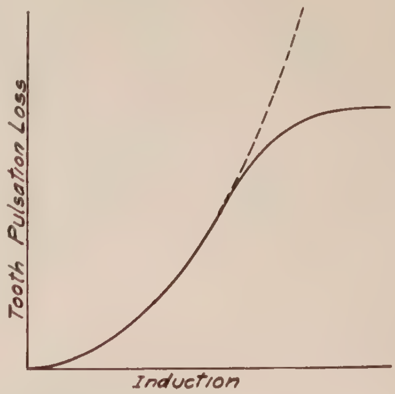

FIG. 1—TOOTH PULSATION LOSSES SHOWING EFFECT OF SATURATION

Saturation is then an important factor in reducing tooth pulsation losses. This, of course, applies only to induction motor rotors with no windings or with slip ring windings, but does not apply to squirrel cage rotors.

RECENT DEVELOPMENTS IN KILOVOLT-AMPERE METERING[1] (SMITH AND RUTTER)

PHILADELPHIA, PA., FEBRUARY 7, 1924

W. H. Pratt: Volt-ampere and volt-ampere-hour measurements seem to be occasioned almost wholly by the problem of making suitable rates for electrical energy when used at low power factor; that is of making rates that will stimulate the raising of the power factor in such cases. From this viewpoint devices of this kind should be in a measure self-eliminating, for once the power factor fairly approaches unity there is little or no excuse for the added complexity of apparatus above that of the watthour meter.

The practical problem does not involve the measurement of volt-ampere hours through a wide range of power factor, in fact almost all cases that arise can be met by a watt-hour meter construction excited at a displaced phase. It is often advisable to use a three-element watt-hour meter for the sake of symmetry of connections.

Since the cosine of small angles remains near unity, it is possible to cover a range of 23 deg. with a simple watt-hour meter excited at a suitably displaced phase with maximum errors of one per cent. This represents a range of power factor of from 92 to 70 per cent, or 80 to 50 per cent, ranges amply large for including possible maximum demand connections for a very large portion of practical cases. A simple duplication of parts with a selective register makes the double angle possible.

In the types of apparatus described in the paper it does not seem fair to expect that errors arising from mechanical causes can be less than one per cent and they are likely to be of an irregular character.

One condition which is quite common does not seem to be well met by the ball types of device. That is the regular or irregular pulsation of power factor arising from such loads as

1. A. I. E. E. JOURNAL, Vol. XLIII, May, p. 441.

machine tools—for instance, wood-working machinery. The roller on the ball would never be where it should be. This criticism would vanish if the roller moved at a speed such as shown in the moving picture, where everything was going fast. But if the roller moves at a leisurely rate, as I understand it does, it seems that in a large number of cases the reading will not be sufficiently accurate.

A. E. Knowlton: Both the kilovolt-ampere metering devices presented in the paper represent commendable progress. It should be noticed, however, that as proposed in the paper, they rest upon a method of potential connections for obtaining the reactive component which is inherently inaccurate on unbalanced loads. An analysis and experimental study of these inherent errors of the "compensator" or "phasing-transformer" scheme of getting quadrature potentials (reported in *Electrical World*, Vol. 82, No. 26) shows the possibility of several per cent of error in power factor, reactive component, and total kilovolt-amperes under certain conditions of unbalanced inductive load. If the loads, which are so important as to require the integration of kv-a. and indication of kv-a. demand, become materially unbalanced, then much of the value and precision of these new devices is lost through the inherent inaccuracy of the means of obtaining the potentials impressed on the reactive meter elements. The very necessity of observing phase sequence in making the connections to the reactive meter also underlies the fact that any unbalance of volt-amperes is registered in the wrong sense by the reactive meter.

The article does not refer to the type of adjustments provided for the purpose of correcting errors which arise in these two meters while in service. Much of their value to the industry depends on the simplicity and directness of those adjustments which must often be made by a meterman who is none too well qualified to deal with delicate and complex instruments. It would appear that the adjustments at the sphere and disks to compensate for dial friction, slippage, etc., would be materially different in nature from those made by the average meterman handling standardized watt-hour meters.

A. E. Kennelly (by letter): The two types of demand meters described, namely, the pantograph type and the ball type, are both ingenious and interesting. They serve to construct mechanically the magnitude of a hypothenuse from the two side components of a right-angle triangle.

As a matter if terminology, it is suggested that the three sides of the power triangle might logically be called: (1) the active power, or active watts, for the base, (2) the reactive power, or reactive watts, for the perpendicular, and (3) the vector or apparent power (vector watts or the volt-amperes) for the hypothenuse. The reactive power is just as truly power as the active power, except that it does not leave the circuit. The indicating instruments for measuring these three powers would logically be named (1) the active wattmeter (ordinarily, for brevity, the wattmeter), (2) the reactive wattmeter, and (3) the vector wattmeter or volt-ampere meter.

When the corresponding energy components are referred to, they might be called (1) the active energy, or active watt-hours, (2) the reactive energy, or reactive watt-hours (3) the vector energy, or vector watt-hours, or the volt-ampere hours. In this case, the reactive watt-hours would be fictitious; because their true summation value is zero. The corresponding instruments might be named (1) the active watt-hour meter (ordinarily abbreviated to watt-hour meter), (2) the reactive watt-hour meter, and (3) the vector watt-hour meter, or volt-ampere hour meter.

A. R. Rutter: Mr. Chairman and Gentlemen: In connection with the kv-a. paper, I believe the title of the paper points out that the purpose of the paper was to discuss two recent developments, and that the title indicates that there should be future developments in kv-a. metering.

Now, in considering either of the types mentioned in the paper, we should consider the commercial accuracy and the commercial demand of the device as well as the theoretical accuracy, somewhat in line with Mr. Pratt's remarks on testing of instrument transformers.

Now, it is one thing to speak of the theoretical accuracy, and another of the practical commercial accuracy. In regard to the measurement of reactive component it was the intention of the authors to point out that there are a number of schemes or methods of measuring the reactive component. A number of these methods are inaccurate with unbalanced currents, and unbalanced voltages. The particular scheme mentioned, that of the reactive component compensator is described as the outstanding method, and by that we meant the outstanding method at the present time. The method of measuring reactive component with the commercial watthour meter and the use of a reactive component compensator is probably the most widely used method at the present time.

Mr. Smith made some remarks indicating that the development of a true sine-meter is quite possible; in fact, sine-meters are being used I believe by the Philadelphia Electric Company. There are at least two different schemes that might be used to give a theoretical accuracy for a reactive meter.

In connection with the comparison of say, the type *R I* meter with other commercial kv-a. meters, I believe that we should take into consideration the commercial accuracy; that is, that the meter employs standard watthour meter parts and standard apparatus in practically all details.

In regard to the adjustment of the meters, both the type *R S* and the type *R I* are adjusted as standard watthour meters. The adjustment of the pantagraph arrangement in the type *R S* or the adjustment of the ball mechanism in the type *R I* depends upon the workmanship in the construction of the register. In other words, these quantities are fixed.

In connection with Professor Knowlton's comment on reactive metering, I would like to call attention to Professor Knowlton's paper in the December, 1923, issue of the *Electrical World*. In an article entitled, "Tests on Accuracy of Reactive Metering," Professor Knowlton has given a very thorough discussion and summary of reactive metering, and in connection with the commercial application of reactive meters, I believe he has summed up the question of using sine-meters or reactive component meters, using the reactive component compensator, with the remark that of the cost of meter administration and the proficiency of meter men in installing, reading and testing meters are to be given due consideration along with the accuracy of registration, there is a question whether any, except method *B*, of the methods outlined can be wholly condemned as too inaccurate for use in the majority of loads.

In designing these meters the designer used the reactive scheme feeling that it was the most widely known method and except with extreme cases of unbalanced voltage no serious error would be introduced. Of course, as we have pointed out on a number of occasions if the demand presents itself, a true sine-meter can and will be developed to measure the reactive component.

Mr. J. M. Jones of Pittsburgh has presented written questions on the type *R S* meter. Question No. 1: "Is the ball used only for indicating power factor?"

The ball is used in the type *R S* meter to give the graphic indication, to indicate the power factors, and to integrate the kv-a. hours. In other words, the ball drives the kv-a. mechanism.

The next question has been answered by the first: "Does this ball have any effect on the graphic part of the meter?"

It drives the graphic part of the meter; that is, it drives the pen. Of course, the clock drives the chart.

"Are standard watthour parts used in this meter?"

Standard polyphase watthour meter parts are used. The comment was made that the meter must be such that the same meter man can maintain them that maintains the polyphase watthour meters.

In this connection, I might remark that the meter is a demand meter and the meters should be maintained by the men that maintain the watthour demand meters or other demand meters. In other words, demand meters require a higher maintenance than the ordinary watthour meters.

"With rapidly fluctuating loads and power factor can the ball meter indicate this rapidly changing load?" Mr. Smith will asnwer that question.

"What is the cost, with and without the graphic?"

In this connection I might say that the relative cost of the meter is approximately double that of the single watthour demand meter.

"Can a demand contact be added?"

Demand contacts could be added to the kv-a. register or to the watthour register.

B. H. Smith: Mr. Pratt, Mr. Hart and also Mr. Rutter mentioned Mr. Jones' question on the ball mechanism: "What is the effect of the ball shifting on the registration of the meter?" By actual test we have found in a given time interval, (in a fifteen-minute interval), if the power factor changes from one hundred to fifty per cent, the error at any load is about one-third of one per cent, so it is very small.

If the power factor comes back again to one hundred per cent in the same interval, the error is corrected, so that over all, there is no error due to the shifting of the ball mechanism. This is very readily checked by counting the revolutions of the watthour meter, and the reactive watthour meter, taking the square root of the sum of the squares and calculating what the kv-a. reading should be.

That ease of checking also lends itself to checking by metermen of the operation of the meter, and Mr. Knowlton's question read by Mr. Warner, referring to adjustments by meter men, the ball mechanism itself will not need any adjustments if it is running properly, and we can determine if it is running properly by counting the revolutions of the disk and reading the record on the chart.

Mr. Magalhaes can see the ball in this meter and we would like to have every one look it over.

The ball is one inch in diameter of solid pure aluminum and weighs about twenty grams, a little over half an ounce.

Later tests included in report to the A. I. E. E. Meter Committee give further information on some of the above points.

AUTOMATIC TRANSMISSION OF POWER READINGS[1]

(Smith and Pierce)

Philadelphia, Pa., February 7, 1924

H. P. Sparkes (Pittsburgh): In connection with remote load indication we have been watching several different systems. In the Pittsburgh territory, with regard to this movement, it means this: When several big power plants are tied together, the growth of that system will eventually develop into a miniature superpower system. This necessitates some method of the load dispatcher knowing the exact load on each station.

Now, if you will go into the matter you will find that it is necessary for the system load operator continually to call his power stations and find the load over the territory. In case of trouble, quite often they can't get the stations, due to line interference or some form of trouble out on the power line. Or they haven't time to get them. At a recent meeting this same point was brought up in the Ohio Electric Light Association. They wanted to know the possibilities of such a scheme on a large power system tied in together with several operating companies. In doing so, it will be necessary there to transmit these readings over several hundred miles. A telephone company, a company at least operating the master telephone system there, is at present installing super-telephone equipment to take care of this new development.

As a result, if the superpower program actually comes through, this remote load indicator problem will be solved by that time, and we shall have something by which the load operators can tell what is going on in various parts of the superpower system.

As to the actual operation of these outfits, I have been carefully watching one system in Pittsburgh to determine whether the thing was really successful by using the various schemes with reference to the Potentiometer system in Pittsburgh. I might say we have operating there one scheme which is very successful. It was used last year at the February meeting of the Institute to transmit the loads of the West Penn Power Company's plant from Springdale to the Chamber of Commerce.

A peculiar incident happened during that time. Everything was running, the meter was operating perfectly, and suddenly dropped to zero. I immediately thought something had happened on the local telephone wires as we were using local wires through the local telephone exchange. About ten minutes later the operator on the System whose load was being used for remote indication came in and asked how it was working.

I said, "We are having trouble."

He said, "No, we had it. We had an excellent load on the plant but lost everything. The telephone wires immediately dropped to zero and gave me that indication."

You can see how valuable the immediate notice of loss of power is to an operating company. That system has been operating satisfactorily. It was one of the first systems installed in this part of the country, and has auxiliary indicators operating in the boiler and turbine room, about 37 in. in diameter which may be seen from any part of the plant. One of these indicators is located in the boiler room where considerable dust is sifting through the air. The meter is enclosed in a steel case and is dust-proof.

P. MacGahan (by letter): The importance of the paper by Messrs. Smith and Pierce lies in the fact that the future super-power system will require the transmission of instrument readings to a remote point. Conversely, the development of such instruments will greatly facilitate and perhaps advance the day when the super-power system will be brought into use.

One of the earliest installations of the remote transmission of instrument readings was that at the Springdale Power Plant of the West Penn Power Company near Pittsburgh where the graphic recording wattmeter readings on a switchboard were transmitted to a load dispatcher's office and to a large boiler room indicator approximately 36 in. in diameter, of the illuminated-dial type. This installation works on the potentiometer principle described in the paper.

In later installations it was found desirable to provide for the totalization of readings in several circuits either in the same plant or in different powerhouse locations or in entirely separate plants. The current equipment described in the paper seems to facilitate obtaining this desired result. By adding the desired milli-amperes a totalized indication or graphic record can be obtained, at any desired location.

When several circuits are in one location, the previous practise has been to construct a totalizing graphic wattmeter consisting of one meter element in each circuit, all tied together mechanically so as to add the resulting power. This system has the disadvantage that whenever an additional unit is to be installed all the previously equipped units have to be changed and the complete totalizing graphic instrument recalibrated. With the proposed electric totalization method, however, a separate measuring unit would be located at each circuit and a totalizing unit installed in such a way as to allow additional units to be installed at any future time without disturbing the original outfit.

The electric transmission of power readings is intimately associated with the subject of remote control on automatic stations, thus it would seem desirable to have a system for the remote transmission of power readings such as would function without interference with supervisory control over the same connecting wires.

1. A. I. E. E. Journal, Vol. XLIII, February, p. 101.

Perry A. Borden (by letter): It is fitting that at this time, when transmission and distribution networks are daily becoming more intricate, there should have been placed before the Institute such a summary of the existing methods of remote indication and totalization of power loads as has been presented by Messrs. Smith and Pierce. By way of further broadening our horizon of such matters I should like to add a brief description of a system which has recently been placed upon the market by a British manufacturer. This is known as the Fawcett Remote Power Indicator; and, while it might be said to fall within the fifth class enumerated, it possesses features which would almost justify its consideration under a separate class.

The Fawcett indicator makes use of a form of thermal wattmeter, similar to that employed in the Lincoln demand meter. In this meter the difference of temperature of two heating elements is proportional to the watts in the circuit being metered; and, it will be remembered, that in the Lincoln meter expanding elements are made use of to give an indication of this temperature difference. In the Fawcett indicator the temperature difference is made to actuate a pair of thermocouples, thus giving at the point of metering a direct electromotive force representative of the value of the power measured. While, in its present form, this device makes use of a direct deflecting galvanometer in its indicator, it would appear that such a method, if combined with a balancing recorder, would present great possibilities for American practise, particularly in large urban distribution systems.

B. M. Jones (by letter): This paper is on a subject which has in recent years become very important, both to the power companies and to the consumers. At the present time, our company is using a method of obtaining the power factor as outlined in Fig. 1 of Messrs. Smith and Rutter's paper. This gives us very good results, although not the most accurate possible. To put in service in consumers' stations equipment to record power factor (or its equivalent) in the most accurate way possible appears hardly worth while for several reasons; one of which is that the equipment would be special, complicated, elaborate and expensive. Another is that it would not be possible for the general run of meter testers who now work on standard watthour meters and a few other meters, to take over the adjustment of these meters without experiencing some trouble and difficulty. Another point against using the most accurate means of measuring power factor is the fact that the instruments for obtaining these measurements would more than likely have to be tested or recalibrated in the laboratory, which would mean that they would have to be taken off the job, transported to the laboratory, tested, retransported to the job and reinstalled; all of which takes time, costs money, and in addition leaves a loophole for disturbing the adjustment during transportation and reinstallation.

Professor A. E. Knowlton of Yale University, published an article in the December 29, 1923, issue of *Electrical World*, on the subject "Tests on Accuracy of Reactive Metering" which was of great interest. In this paper, Professor Knowlton goes into the question from two or three different angles, and two or three methods of obtaining the power factor are thoroughly covered. His conclusions are very interesting, especially the third conclusion, in which he states that, "If the cost of meters, the cost of maintenance of meters, and the proficiency of metermen in installing, reading and testing the meters are to be given due consideration along with the accuracy of registration, there is a question whether any of the methods except Method B (outlined in his paper) can be wholly condemned as too inaccurate for use with the majority of loads."

To the writer's mind, this is the most important conclusion of Professor Knowlton's paper, and is the one in which power companies are primarily interested just now. Most power companies have thousands of meters of very similar types and the metermen are very proficient in installing, maintaining and testing these meters. To run in a new instrument of complicated design, and call upon them to install, maintain and test it will doubtless bring on errors which may counteract the increase in accuracy. The scheme outlined in Fig. 1 of Messrs. Smith and Rutter's paper and also Fig. 3 of Professor Knowlton's paper is one which uses standard watthour meters with the phasing transformer, and will undoubtedly meet with the approval of the meter-maintenance crew who have to live with the equipment and make it operate with a fair degree of accuracy. This equipment is made by several manufacturers and can be obtained on very short delivery and at quite reasonable prices, and can be tested the same as standard watthour meters.

There are a few points and questions that the writer wishes to bring out regarding the "R. I." kv-a. demand meter which was discussed in detail in Messrs. Smith and Rutter's paper, a sample of which they exhibited.

1. Is the ball used only for indicating power factor?

2. Does this ball have any effect upon the graphic part of the meter?

3. Are standard watthour parts used with these meters?

4. Meters must be such that the same metermen will maintain them who now maintain polyphase watthour meters?

5. In very rapidly fluctuating loads and power factors, can the ball meters indicate the rapid changes accurately? This is very important to most companies on such loads as coal-mining hoist loads and similar loads where the hoist load is a great portion of the total load and is on for a few seconds, 15 or so, and off for 15 to 30 seconds.

6. What is the cost of this meter with and without the graphic parts?

7. Can a demand contact be added to this instrument to operate the usual demand meters?

8. What simple method can be used for testing this meter in the field so that the metermen will know that it is fairly accurate without having to take it to the laboratory for each test? The writer considers this very important, as the matter of taking this meter to the laboratory every time to make a test is objectionable and is to be avoided. If a simple test or check can be made on the meter regularly and it be taken to the laboratory periodically for a thorough test once a year or every six months or so, it is much to be desired.

9. How much does the ball slip and what method can the meter testers use to determine if the ball is slipping? This is especially important where there is a great amount of dust in the consumer's plant where these meters have to be installed.

The question of power-factor clauses in rates is a very important one and has come up in recent years, and is now written into quite a few new contracts that some power companies are making. The ability to obtain accurately and conveniently a record of the power factor for the joint benefit of the consumer and power company is greatly to be desired, and with the present equipment available, this can be done. This is largely due to the perseverance of the manufacturers' meter designers.

B. H. Smith: Referring to discussion by letter from B. M. Jones in answer to his questions 1 to 9, they may be answered as follows:

1. As mentioned in the text of the paper, the ball is used not only for operating the indicating power factor mechanism, but also combines the reactive component and power component meters so as to give a quantity which is proportional to kv-a. hours. This ball mechanism is the heart of the meter and is the mechanism which makes a kv-a. reading possible.

2. The ball drives the pen mechanism which registers kv-a. demand. The kw. indication on the pen is, however, obtained directly from the kw. element, as explained in the text of the paper.

3. The meter elements are standard polyphase watt-hour meter parts.

4. With proper instructions it is expected that this meter

can be maintained by the same men who now maintain polyphase watt-hour meters.

5. In rapidly fluctuating loads there is no likelihood of errors in this meter, but with rapidly changing power factors the kv-a. element reads somewhat low, due to the motion required for the ball mechanism to adjust itself. It is found that with power factors changing once a minute from 100 to 0, the error is about four per cent, and changing from 100 to 70 every minute, the error is about one per cent. If the power factor changes every few seconds, the error would be somewhat greater.

6. The cost of this meter is in the neighborhood of $300. It is not available without the graphic parts.

7. Since the meter gives complete demand readings, it is not necessary to add demand contacts.

8. A simple method of testing this meter in the field is to allow the kw. element to rotate a proper number of revolutions at unity power factor and see if the pen gives a correct reading. A similar test may be made at zero power factor, counting the revolutions of the reactive element.

9. Since, with the meter running properly, the pen furnishes practically no load upon the ball mechanism, there is no tendency for any slipping, but this point can readily be checked by the test given under 8. Complete instructions for the operation and maintenance of this meter are covered by the instruction book which is furnished with the apparatus.

R. F. Pierce: In regard to the Fawcett scheme, although I am not intimately familiar with all the details of it, yet it seems as if, using a thermocouple and small e. m. fs. that are generated thereby, a very delicate receiving instrument would have to be used and the line resistance for considerable distances would cut down the sensitiveness of the response. Of course, a potentiometer method of taking readings could be used, but that is not within the scope of this paper. We are covering automatic methods and to use a very sensitive hand-operated potentiometer method which might be necessary with long distances with this scheme would not give to the operator at all times a knowledge of the load conditions at various points.

QUADRANT ELECTROMETER FOR MEASUREMENT OF DIELECTRIC LOSS[1] (Simons and Brown)

Philadelphia, Pa., February 7, 1924

S. J. Rosch: I would like to ask the authors concerning the limitations of the apparatus and the measurements. For example, can we use it on 22,000 or 33,000 volt cable?

If I remember correctly, Mr. Brown referred to a limitation of 0.3 watt, in other words he claimed to have measured as high as 0.3 watt. If we take the care of a 33,000 volt cable and measure its dielectric loss at say 80° or 90° centigrade, the power factor of a good cable at that voltage and temperature would run about 3 to 4 per cent and the corresponding loss would amount to approximately one watt per foot.

I am also under the impression that the value of this paper would have been enhanced considerably, had the authors given some relative data on measurements obtained with both the quadrant electrometer and the dynamometer wattmeter methods. Curves of this nature would in my estimation, have given a better conception of the value of the method advocated.

D. M. Simons: Mr. Doyle and Mr. Rosch both bring up the question of our not having shown any actual measurements of losses in cables. We did not believe that the present paper was an appropriate place for showing data of this kind, since this is an article on an instrument rather than on cables, and our only interest was in losses which we could measure and which we could also calculate, and thereby check the accuracy of our equations.

The method Mr. Doyle shows is very interesting. The more methods we have the better off we are, in measuring the extremely low losses which are difficult measurements at best. I might add that in our company we have two separate methods: in our Perth Amboy laboratory we have a special bridge for measuring losses, and in Pittsburgh we use the quadrant electrometer. It is very convenient to be able to check measurements made by two such different methods.

In reply to Mr. Doyle's question, we have used the electrometer practically entirely for research work, and not for routine measurements; we have used it almost entirely on single-phase work. Seven or eight years ago, however, we made three-phase measurements with the electrometer, using the deflection method. It of course might be used equally advantageously with the zero method.

Mr. Rosch asked whether the electrometer may be used for measuring losses in reels of 22,000-volt and 33,000-volt cables, especially at the high temperatures. This question was apparently asked particularly because we showed in our tables the results of measuring extremely small losses. The electrometer can, of course, be used very conveniently for the measurement of larger losses and higher power factors, and, in fact, in these cases some of the difficulties mentioned in our paper practically disappear, the effect of the shunting capacity and needle current being negligible, and the measurements can usually be made with extreme ease and rapidity. In other words, the same instrument used to measure a 10th or 100th of a watt at low power factor can easily measure kilowatts, the only requirement being that considerably lower values of quadrant resistance will be required.

RECENT ADVANCES IN THE MANUFACTURE AND TESTING OF STATIC CONDENSERS IN POWER SIZES[1] (Marbury)

Philadelphia, Pa., February 7, 1924

J. R. Craighead: In any engineering development which leads to the construction of devices of broadly new characteristics, there are usually two stages. The first stage consists in using available materials to produce the device. These materials are rarely exactly adapted to the purpose which they are to serve. The result of this step is usually a costly, heavy, and sometimes unsatisfactory device.

The second stage then must automatically follow. This stage includes the examination of the materials individually, to determine their characteristics, and frequently the development of a better grade of materials to serve the specific purpose more fully. The result of this stage is a device which eventually meets good engineering practise, suitable in cost and in service as related to cost.

In the development of the static condenser for power factor correction, we have completed the first stage and are now reasonably well along in the second stage. Condensers with commercial papers of various thicknesses, various impregnating materials, and various structures (paraffin being at least typical of the general nature of the impregnating materials used) constituted the result of the first stage. These condensers stood up satisfactorily in service under some conditions, but in order to get general satisfactory service from them, it was necessary to reduce the stress per mil in the insulation to the general order of the stress per mil in cables, otherwise they were not permanently satisfactory. The result was that size and cost made the commercial prospect of a condenser that would stand up rather uninviting. Consequently, it became necessary to begin on the second stage.

The second stage consisted of examination of the materials and development of the most suitable. Oil has been very largely substituted for other impregnating materials. We have subjected the type of oil selected to new methods of treatment in order to secure better conditions regarding dryness, purity, and dielectric strength.

Some study has been given to substitutes for paper, of which there is a number available, but the general results indicate the superiority of paper when properly made and applied. We have investigated the manufacture of paper, with a view to perfecting

1. A. I. E. E. Journal, Vol. XLIII, December, p. 1147.

1. A. I. E. E. Journal, Vol. XLIII, February, p. 114.

the quality, as to chemical purity, absence of conducting particles, and absence of holes, which tend to cause breakdown.

We have investigated the oil in bulk, as to dielectric strength and considerable improvement has been secured in the quality. We have also investigated this in comparison with the same oil when partially immobilized by the presence of dividing material such as paper.

The result has shown the immense advantage attainable by the use of a number of thin sheets immobilizing the oil very perfectly as compared with a much smaller number of heavier sheets.

The mechanical arrangement of the active parts of the condenser and their relation to electrostatic troubles have also been studied. The results of these studies are embodied in the present condensers which we manufacture.

Regarding Mr. Marbury's paper in detail, it appears to be chiefly a plea for the construction of condensers with a liberal thickness of insulation, as opposed to a construction with insulation of less thickness, but more carefully selected. This is actually a purely commercial question. The factor of safety in the condenser can be made equally great by either means. Consequently, it is not a question of which condenser will break down if the engineering is equally correct in both cases, but it is a question of which condenser will cost the more in the long run, considering first cost, failure or destruction, size of space occupied, and necessary conditions of handling.

Our own experience has indicated the superiority of condensers using a better grade of insulation, when backed up by careful engineering and extremely careful factory practise. We have made considerable investigations along the line of cheaper and more abundant insulation and the results obtainable have not appeared superior to our present method.

Eventual design in condenser practise will be determined by experience in the field rather than by the results of any shop tests that are now available. Meanwhile, the subject is of great interest for discussion before the Institute.

In the last column of page 3, in Mr. Marbury's paper, his language implies the possession of a large amount of interesting data. These data apply to subjects which are not yet by any means fully settled, and it would be of great value if he could contribute some of that to the files of the Institute.

E. K. Shelton: Mr. Marbury's paper calls attention to a development which has become of vast importance in the last few years, due to the intensive consideration given to the problem of low power factor loads. The possibilities in the power factor correction field put the static condenser in a position of importance in the industrial application of electric power.

The development problem involved in the design of static condensers upon analysis is found to be concentrated in the dielectric, its characteristics, treatment, and use. Several references are made in the paper to the advantages of a high working stress, but we are informed that a final selection was made of conservative stresses as used in other apparatus. A working stress of 145 volts per mil is given for the condenser construction as described. As a point of fact, working stresses in other electrical apparatus reach a maximum of 60 volts per mil so that it is evident a value of 145 volts per mil is already two to three times conservative stresses used in other electrical apparatus. It is further indicated that a wood pulp paper is used. This is a type of paper commonly used in cable and transformer work. Let us see what this question of the selection of the working stress means.

We must keep in mind that the application of static condensers to power factor correction work is largely an economic problem involving reliability, a reasonable initial cost, and the question of size or weight. Reliability obviously must be obtained in any case. The initial cost must be reasonable to permit of a satisfactory return on the investment, else other means of correction will be used or the penalty accepted. Size or weight are factors of importance as this is a device that is added to an existing industrial establishment and must, in the majority of cases, be installed in an already rather completely utilized space. It is quite evident that by mere bulk application of the usual quality of insulating materials as commonly used in other types of electrical apparatus, and with operation at stresses equivalent to those utilized in such aparatus, condensers can be built that may have reliability but at the expense of size and cost. In considering the advantage gained from the use of a higher stress, it is only necessary to remember that the corrective capacity obtained from a given unit area and thickness of condenser dielectric varies directly with the ratio of the squares of the applied voltages. Thus, an increase of 100 per cent in the working stress on the same dielectric means four times the corrective capacity obtained. If, by the use of a higher quality material, one-half the thickness of dielectric can be used for a given voltage, the same ratio holds, since twice the active area can be obtained in a given volume. This means one-fourth the bulk and weight for a given rating of equipment. Assuming any given economic limitation in size or weight, such an increase in working stress extends the range of application to four times the original limit. Certainly this is argument enough for a real engineering development that such advantages may be realized.

I have been intimately connected with a very extensive development on this same problem. Early work showed that ordinary grades of thin paper were entirely unsuited to this work as they would not give satisfactory results at the higher operating stresses. Such limitation, however, is no argument for retarding real engineering advance on a development of this nature. Paper, while suited for insulation work, was not originally developed with such application in view. Intensive cooperation with the paper manufacturers has already resulted in the production of papers of a quality never before obtained, and this on a basis that makes them entirely available commercially for this work. Conducting particles have been reduced to a very low value. By the selection of the proper materials, a dense paper has been produced that shows a remarkable comparison from the porosity standpoint with the best grades of wood pulp or Kraft papers. Experimental data between 2½ mil wood pulp paper and ½ mil paper of the type developed shows $^1/_3$ to ¼ the porosity for the ½ mil paper. A comparison of five sheets of this ½ mil paper with one sheet of 2½ mil wood pulp paper so that equal thickness is obtained shows approximately 1/15 the porosity for the 5-sheet construction. The advantage gained from the use of such high quality papers is evident. The use of a large number of these thin sheets for a given thickness of dielectric actually decreases the possibility of difficulties due to line-up of conducting particles or holes. A given corrective capacity of condenser with a few sheets of comparatively thick papers means a much larger active area over which this lining up may occur, combined with the greater percentage effect of partial lining up on two or three sheets.

Equally important advances have been made in the treatment of these materials. Methods that are entirely satisfactory when the ordinary stresses in other electrical apparatus are considered, prove utterly inadequate at these higher values, but engineering advances in any line necessarily involve changes and improvement. Advances already made along these lines have shown their value not only to the condenser problem but to the whole art of insulations in general.

Following out this line of development, condensers have been manufactured on a commercial scale that have been in successful operation for periods considerably over a year. 2300-volt units of this type have a breakdown voltage averaging 15,000 so that a factor of safety of approximately 6 is obtained. The normal working stress is 350 volts per mil. In comparison with the 11 pounds of paper per kv-a. required with the 145 volts per mil stress, only one and one-half pounds are used per kv-a. The development work that has already attained such remarkable

results has directly benefited the whole electrical art. A definite advance has been made in the direction of more efficient utilization of insulations and in our understanding of dielectric phenomena. The future promises further progress along these lines.

J. E. Shrader: It was my privilege to have done some of the research work along the lines of the development of static condensers when the Westinghouse Company took up this problem, and since I have been called upon, probably something regarding the early work which was done might not be out of place.

It has been realized, not only in the manufacture of condensers, but in all lines of insulation, that the amount of moisture in the dielectric is a factor of very great importance, and also, that to get out the very smallest fraction of the moisture, the dielectric properties are increasingly proportionate.

The early practise was to boil the stacked condenser in oil at atmospheric pressure. This did not appear to me, when I took hold of the problem, to be a very satisfactory method. We first dried the stacked paper condenser in a vacuum at about 125 deg. cent., at which temperature no chemical breakdown of the paper occurred. After prolonged treatment, the oil was admitted into a vacuum space where it was heated before coming into contact with the condenser. This is what we call the spray process. In this process the oil was drawn under vacuum, heated, and allowed to spread through an open space in the vacuum, where it was released in the form of spray. Tests upon this method have shown that not more than a few ten thousandths per cent of moisture was still present. The oil was now introduced into the dried paper and there was no chance of moisture being absorbed in the process.

Any one who has studied the subject knows that by exposure to moist atmosphere, paper or oil will absorb a considerable amount of moisture. For this reason, the condenser was packed inside a vacuum tight vessel and after impregnation it was not again exposed to atmospheric moisture.

C. N. Johnson: The design of the static condenser has been well covered in Mr. Marbury's paper. The problem of the application of the condensers would seem to present a topic for an interesting paper at some future Meeting.

The need of a device for correcting power factor on lines supplying industrial load, is becoming more evident each year. With a reliable corrective device now available, which requires very little energy for its operation, its general use may be expected where a study of conditions shows that the installation cost is justified by the reduction in power losses and improved line condition.

Advances in meter design are keeping pace with the development of corrective devices. At this Meeting a paper is being presented showing some remarkably new developments in metering on a-c. lines. This metering device meets a general demand for a means of indicating the actual kv-a. load, and should bring about a more general use of power factor corrective devices.

Everett S. Lee: In the second column on page 2 of Mr. Marbury's paper we find him making reference to the increased dielectric strength which may be obtained over that of the oil itself by making use of the barrier action, wherein the oil is held immobile to eliminate that motion which we find in oil in bulk when it is subjected to an electric field.

I think you are probably all familiar with the fact that if you have a bulk of oil and electrodes immersed in the oil, and subject that bulk to an electric field, there will be a motion of the oil, and any imperfections which may be in the oil are brought in the vicinity of the electrodes, with consequent breakdown at a low value.

Now, if we can utilize the principle whereby, if we put barriers in between those electrodes (and in a condenser those barriers are in the form of a number of very thin sheets of material which in turn have been well impregnated with good oil) we get thin films of oil separated by thin sheets of impregnated material, which means that the entire mass is held stationary, as it were, with very small liability of this movement which we find in bulk oil. Of course, we derive greater benefit from that consideration if we use a relatively large number of thin sheets, rather than a relatively small number of thicker materials. Consequently, that is one of the reasons why it seems quite desirable to, as far as possible, make use of that characteristic which we know is true and certain. At the same time, using the larger number of sheets, we decrease the liability of imperfections in the individual sheets lining up in such a way as to cause a path where the dielectric strength may be low.

In speaking of oil, I would call your attention to the fact that care is needed in its use as has been brought out by Dr. Shrader, just as care is needed in the selection of the paper which we employ. During the handling of the oil we must be very careful that it is not brought in contact with the air at such temperatures and in such a way that air may be absorbed by the oil, otherwise, although we so arrange the condenser cases that air may not come in, we still may have some air therein. Also, we must be sure that moisture is not contained in the cases, and that in the treating of the oil at such temperatures as we may use, no deteriorating effects are brought about.

Cooperation between the condenser manufacturer and the manufacturer of the oil has brought about a much better product, just as cooperation between the condenser manufacturer and the manufacturer of paper has brought about a much better product, and this cooperation we feel has been well worth while to the art and to the industry.

I dwell on these points particularly, one reason being the statement made in Mr. Marbury's paper that the loss in condensers, of a manufacture with which he is familiar, is about one-half of one per cent, whereas it is quite easy to obtain losses in the neighborhood of two-tenths of one per cent in condenser units where some of these other factors are not only taken into account, but are actually employed in the design and in the manufacture of the units.

The method of test which Mr. Marbury has outlined seems to have very desirable features, and if the accuracy which he has suggested can be obtained as easily as he has said, it is a method which probably will come into use. I would not, however, have you feel that the use of an electro-dynamometer wattmeter need require a whole laboratory force to take measurements therewith, as we find that it is just as easily possible to use such a wattmeter, following methods which have been outlined for years, I believe first perhaps by the late Dr. Rosa, of the Bureau of Standards. Those methods, together with the use of the dynamometer wattmeter, can be used by factory men in measuring losses in condensers in from one-half to one minute per unit.

I note in connection with the tests, that the test voltages used seem to be those as used in connection with electrical machinery; that is, about two times normal plus a thousand, whereas you may recall that in cables the values are two and one-half times normal for five minutes, rather than for one minute, as in the case of electrical machinery. In other words, there may be variations in the kinds of tests that are applied to different kinds of apparatus, and I believe there is a tendency on the part of many people who are studying these problems at the present time to say: "Perhaps we can get a more suitable test by using the lower values of potential applied for a longer time, rather than the higher values of potential applied for a shorter time;" that is, when the frequencies are at the value for which the apparatus is designed.

It seems that in the art today there is such a need for better insulation that if we can obtain better materials and if we can better the performance of insulating materials through these more refined manufacturing methods, it is much better that we try and do it, rather than to bring the condenser art down to the same level as we find in other types of apparatus. We feel that at the present time there is much more need for more serviceable insulation in other branches of the art than there is in the con-

denser game, and if, in studying these questions through the manufacture of condensers, we can better the insulation that may be available for other branches of the art, we certainly have gone a step in the right direction, rather than to allow ourselves to use what we may now have and just continue as we are, without having at least put our minds and abilities and resources to work to discover something better.

J. D. Stacy: The paper presented by Mr. Marbury gives a very comprehensive description of the problems of manufacture of condenser units in power sizes, and touches briefly on the question of application of these units to power circuits. It is in connection with the application problem that I wish to point out that since a condenser draws a current proportional to the frequency of the applied voltage, any harmonics present in the voltage wave will produce harmonic currents which, under certain conditions, may predominate, and the corrective effect of a leading current may be destroyed totally or in part by the introduction into the system of these harmonic currents which are just as detrimental in the loading of lines, cables, transformers, and generating equipment as the lagging current for which we attempt to correct.

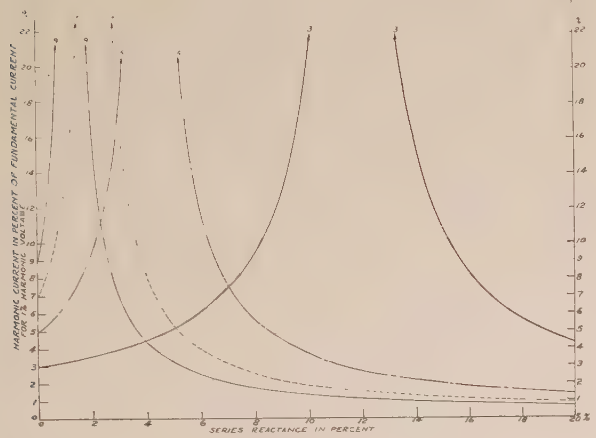

Fig. 1

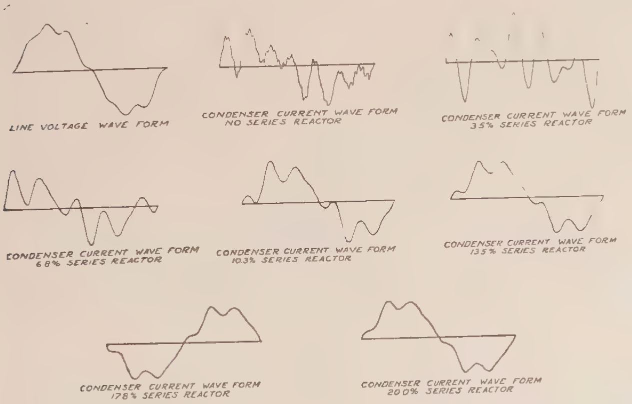

Fig. 2

Referring to Fig. 1, it is apparent that resonant conditions for any odd harmonic above the third may occur with series reactance of 5 per cent or less. These values of reactance lie within the range of line reactances encountered in distribution circuits and the chances are excellent that in applying condensers without reactance, many specific cases will be found where resonant or nearly resonant conditions with harmonics are present.

Experience has shown that line reactance does affect the operation of a condenser equipment. I know of two systems on which condenser equipments installed on very short feeders did not operate satisfactorily, but these same equipments, when moved to the ends of long feeders connected to the same bus as before, gave excellent satisfaction.

Fig. 2 shows a voltage wave form of a 2300-volt distributing bus of a large operating company on which it was desired to install a static condenser, together with condenser current wave forms with several values of series reactance. Calculations of the combined harmonic currents based on readings taken with a hot-wire ammeter, indicate that the combined harmonic currents with no series reactor were 73 per cent of the fundamental current, and with 3.5 per cent series reactor, 214 per cent of the fundamental.

Contrasting with these very poor wave forms, it is evident that when a 20 per cent reactor was used, the current wave form was quite comparable with the voltage wave form.

The effect of harmonic currents on the line current of a circuit which has had sufficient leading current of fundamental frequency added to correct the power factor from 70 per cent to

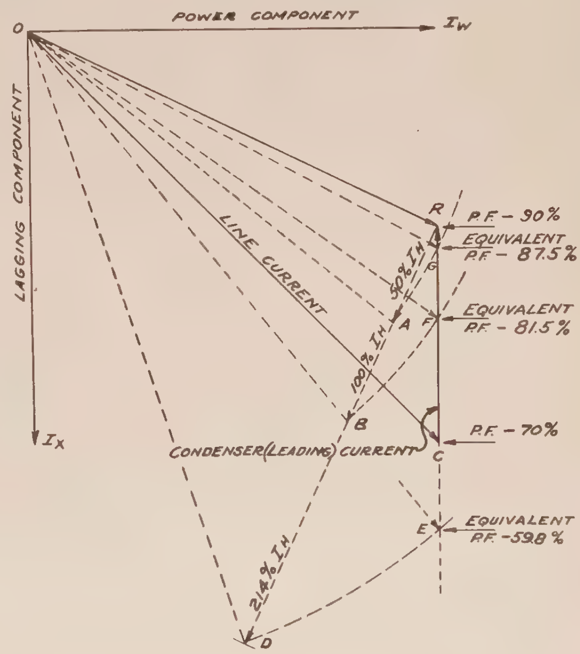

Fig. 3

90 per cent is shown in the diagram Fig. 3. With combined harmonic currents equal to 50 per cent of the fundamental frequency leading current represented by $R\ A$ in quadrature with $O\ R$, the resulting line current is given by $O\ A$ and the equivalent power factor is 87.5. With 100 per cent harmonic current, the line current is given by $O\ B$ and the equivalent power factor is 81.5 per cent. With 214 per cent harmonic current, which is the value just mentioned as applying for the wave form with 3.5 per cent reactance in Fig. 2, but which is by no means the maximum value obtained in tests on other systems, the line current is represented by $O\ D$ and the equivalent power factor is 59.8 per cent. In other words, by the installation of a static condenser under such a condition, we have increased the line current and lowered the power factor.

The only practical method of being certain that a condenser can be furnished to perform its duty under all ordinary system voltage conditions is to furnish with it reactance sufficient to reduce all harmonic currents to a small percentage of the fundamental.

E. F. Northrup: Mr. Marbury's paper is a forceful, and concise statement of facts and information gained from wide experience and based on sound knowledge.

The power static condenser is almost universally thought of in connection with power factor correction on light and power circuits. There is however a development in the industry—that of ironless inductive heating-in which the static condenser plays a primary role.

All heating by high frequency currents—10,000 cycles or thereabouts—is only made possible through the employment of the static condenser. Ironless inductive heating using current of such moderate frequency as can be obtained from turbo or motor generator sets gives promise of being widely used, and here also static condensers find important application for power factor correction to secure economy.

It has been completely established that using ironless induction the rate of heating is satisfactory even when using currents of a frequency which can be readily obtained from alternators of substantially standard design.

The sole unfavorable feature of ironless inductive heaters is connected with the low power factor which is more or less inherent in the method. Heaters employing currents of medium frequency when applied to the heating of non-magnetic material have ordinarily a power factor of about 40 per cent. From a cost standpoint we must consider the equipment furnishing the power as made up of two units;

One to supply the in-phase component of the volt-amperes and one to supply the wattless component.

Or one may, of course, use a single unit, the generator, which is made large enough to supply both the in-phase and out-of-phase components. For a 40 per cent power factor uncorrected a single generator to take care of both components would need to be two and one-half times the size of a generator required to supply the same power at unity power factor.

In estimating the cost of an installation for ironless inductive heating it must always be inquired whether in a particular case it is more economical to use a single unit to take care of both components, that is, a unit having the kv-a. rating of the heater; or to supply two units,—a generator to develop the in-phase component of the power, and a static condenser to supply the out-of-phase component.

Any progress made on lowering the cost and in increasing the reliability of static condensers for supplying the out-of-phase component of the kv-a. supplied to ironless inductive heating devices has a directly favorable bearing on the economic feasibility of this highly important branch of the industrial use of electric power.

These remarks apply whatever frequency of current may be used for the ironless inductive heating. While the capacity of the condensers shunting the line to bring the power factor to unity decreases as the frequency chosen increases, the kv-a. of condenser required is independent of frequency used. Hence, whether one uses high, medium, or low frequency for inductive heating, it is of prime importance to so design the inductor that the wattless component shall be as small as possible, but when this has been done, it becomes of great importance to secure the needed kv-a. of condenser at the lowest cost possible.

If such cost becomes sufficiently reduced it will prove economical in all cases to use two units;—one to supply the power and one to supply the wattless component of the kv-a. rather than make use of a single generator of capacity sufficient to furnish the entire kv-a. needed.

Mr. Marbury may well include, therefore, as a most important use for the static condenser its adaptation to the art of ironless inductive heating—now in steady progress toward extenive use.

G. D. Robinson: I am sure that there are some who are interested in the use of these condensers with d-c. circuits. If to be used with direct current apparently a condenser should be given a d-c. test.

A breakdown test performed on one of these units has led me to believe that the d-c. voltage which we may use with one of these condensers falls far short of the a-c. voltage.

I would like to ask Mr. Marbury what ratio exists between the a-c. and d-c. ratings of these units. Also, what is the ratio between the voltage to be applied on a-c. test and the voltage which may be applied on d-c. test

H. L. Curtis: The method which is outlined here indicates that Mr. Marbury makes a check by measuring both inductance and capacitance together and then each independently. I wish to call attention to the fact that that may not be a check at all. I have been working on methods of measuring condensers of this value for two or three years, and I have tried absolutley independent methods for making the measurements, and it is not easy to get those which will check. I merely wish to call attention to the fact that in order to get satisfactory checks it is necessary to use methods which are quite independent one of another.

Ralph E. Marbury: Mr. Craighead has given a brief history of the development of a static condenser with which he is familiar. While such a resumé is largely historical, there are certain points on which opinions differ.

The art of condenser manufacture is new. In all radically new apparatus questions arise which cannot be quickly answered. With static condensers the most important problem is the selection of insulating material and safe working stresses. The safe working stress varies with the quality and quantity of material used, operating temperature and character of service. The cost of the condenser depends largely on the cost of insulation. The quantity of insulation required depends on the working stress.

As Mr. Craighead points out in the early development of static condensers, wax impregnated insulation was soon found to be uneconomical, on account of the very low safe working stress.

The outstanding advantage of oil impregnated paper insulation was that the safe working stress was higher than that for solid insulation. The safe working stress for wax impregnated material was not definitely known, and while laboratory tests demonstrated instantly the superiority of oil and paper, time alone could establish the limits.

The first outstanding application of static condensers was for the correction of power factor. While the low power losses give condensers an advantage over other forms of corrective equipment, probably the most important feature is that of small maintenance and no attendance. To fully capitalize this chief advantage the device must be reliable.

For a given material the life of the condenser is indefinitely long below a certain critical working stress. When this stress is exceeded the life of the device becomes shorter, and the performance variable. This critical stress may differ in individual condensers manufactured under identical conditions, due to variations in the material itself or to other factors. This same characteristic would be noticed in most any material worked near the limit or where the limit varied with operating conditions.

Even if all the factors establishing this critical stress were definitely known and perfectly controlled, it would be unwise to work too near this maximum safe stress. Since, however, this is not the case we can only be governed by experience, and in choosing a stress we should introduce a sufficient margin to take care of all conditions that may arise.

We have available much data on insulation stress in similar apparatus extending over many years. These data cover working stresses from 20 to 100 volts per mil. During the development of static condensers thousands of laboratory hours were obtained of insulation as used in condensers, with stresses up to 1100 volts per mil, or over twice the average breakdown of the average insulation used in other apparatus.

If we should combine this laboratory experience with other insulation history we might select as a normal stress for static condensers 400 to 500 volts per mil. This would be expecially true if our choice were influenced by the fact that the size varies inversely as the square of the ratio of stresses. If the working stress is divided by 2 the size will be multiplied by 4.

The problem may be handled commercially in one of two ways. First:—A high stress may be adopted based on laboratory experience alone, and gradually reduced over a long period of manufacture until an entirely reliable device is provided. Second:—A stress definitely well below the safe stress may be adopted, and gradually increased over a long period, until the maximum of perfection is obtained.

In either case the final result would probably be the same, but years of experience in other apparatus has demonstrated the advantages of the second plan.

At first it appeared impossible to proceed along the second plan without excessive costs, and that it would be necessary to start at a comparaitvely high stress such as 300 volts per mil. In order to entirely follow the plan outlined, however, a stress of 145 volts per mil was chosen without regard to cost, and from this point the development became an economic study.

It is the object of this paper to briefly describe the work done which made possible a complete line of static condenser worked at stresses of 145 volts per mil, and at costs no greater than originally expected for 400 volts per mil, designs even though about seven times as much material was required.

A study of materials was made covering the entire range of cost and quality. Some paper cost as much as twelve times that of another. On examining the cost curves it was found that cost depends more on thickness than stock used. This is tied up with the tonnage that can be produced with a given outlay of paper making machinery. The electrical quality is about the same for either linen, wood or cotton fiber. The cost increases as the thickness is reduced, due to the reduction in tonnage, at the mil, to the necessity for using more costly stock, and to the increase in waste. The dielectric losses are hardly effected by the thickness or kind of stock, so long as impregnation and chemical purity remain constant.

For a given dielectric thickness the breakdown is increased by reduction of porosity of the paper or by greater subdivision of the oil by thinner and thinner sheets. If the breakdown is plotted against cost of a given area of material, the thicker more porous and less expensive materials prove far better.

The net result of this economic study of materials, together with improvements in mechanical construction method of impregnating and testing was the two-kv-a. 2300-volt 60-cycle unit, designed with a working stress of 145 volts per mil, and with a cost of no greater than originally expected for a 400-volt per mil design. Many thousands of these units have been manufactured and some have operated nearly three years, and not a single insulation failure has occured. The fact that 145 volts per mil was well within the safe limits has been fully established in service.

With the complete elimination of insulation failure and the ability of the condenser to withstand all line surges and periods of over voltages, individual fuses were no longer necessary. The increased surface of the units for radiation and the elimination of individual fuses made possible a very compact frame assembly, the overall dimensions of which were not a great deal more than those of the early experimental 400 volts per mil type.

The weight of the units per kv-a. was reduced by the elimination of all metal with the exception of the containers and metal conductors.

In the early stages, dielectric loss measurement was a laboratory process, and it was unsafe to make loss measurements until after over-potential tests had been made, due to the possibility of damaging very delicate low power-factor wattmeters in the event of failure of the unit. Such improperly impregnated units were therefore found and destroyed on the voltgae test. A very reliable and fool-proof means was developed for making loss measurements, where an improperly impregnated condenser could not damage the equipment if failure occurred. This made it possible to select and return for retreatment such units without damaging them, except in rare cases where manufacturing errors were made in putting in the insulation.

This loss measuring equipment reduced factory scrap to a very low figure.

Other methods were developed for controlling the quality of the condensers throughout the entire manufacture.

All units are given a one-minute overpotential test of 2¼ times rating plus 2000 volts for one minute. This test is made generally on 25 cycles.

I do not wish to leave the impression that research ceased when it became possible to work at low stresses economically. Units have operated in the laboratory where their daily performance could be observed and a continuous study of materials is carried on.

One point that has been fairly well established is that a material which breaks down at 400 volts per mil. and is operated at 100 volts per mil. gives more dependable service than one which breaks down at 1600 and is operated at 400, even though the ratio between working stress and operating voltage is the same in each case initially.

Mr. Shelton emphasizes the importance of the porosity of paper. Low porosity is a desirable characteristic, except in cases where the cost of obtaining it overbalances its value. The writer has never seen ordinary paper manufactured here or abroad which was entirely free of holes. This can only be accomplished by subjecting the paper to chemical treatment which lowers its electrical quality. When thousands of square inches of material are used in a single condenser, holes may line up somewhere with even the best paper yet produced. When low stresses are used, and low porosity not depended upon, such a line up has little effect on the condenser, neither does the line up of a few metal particules.

I wish to agree with Mr. Lee that the dielectric losses can be reduced to 0.2 per cent by very careful treatment. This is desirable when very high stresses are used since the stored energy per unit volume of material is great. We work toward an average of ½ per cent on complete equipments. Even with this average many units run even lower than 0.2 of 1 per cent losses.

Since entirely satisfactory performance has been obtained with loss average of 5 watts per kv-a., the only other reason for holding it lower is power cost. The difference in power loss even at three cents per kw-hr. would not justify the special care required, to bring losses down to even 0.3 per cent.

I do not mean to create the impression that the electro-dynamometer is an impractical device. This instrument has been found to be most satisfactory for low power-factor measurements. Any one familiar with this device knows, however, that as the voltages at which tests are made is increased, the resistance of the potential circuit must be increased, and that this resistance, which sometimes must be as large as one megohm, must be free from distributed capacity and inductance, as a slight amount of either will cause large errors. In addition, the arrangement of the resistances with respect to other parts of the circuit is of great importance. In measuring condensers varying in capacity from ½ to 150 microfarads, and at voltages from 20 to 5000, considerable manipulation is needed, requiring a technical knowledge of the principles of the instrument. In addition should an accident occur, such as attempting to test a short-circuited or defective condenser, the meter will be seriously damaged.

The scheme of operation of the inductance test equipment has been fully covered in the paper. However, I might add that should a defective condenser be connected to the test no harm can come to the meters, as the voltage will not build up. If the condenser breaks down on test, the voltage drops to a low value, since the device operates on the principle of series resonance.

In reply to Mr. Curtis, I wish to point out that the calibration of the inductance was a laboratory operation which extended over two months and every precaution was taken to obtain a very accurate calibration. It is true that a measure of condenser losses and inductance losses separately and combined will not always show up a phase angle error in the potential circuit. However, this check was not solely relied on as evidence of correct measurements, but merely made as a final check to note any inconsistency. Once a complete calibration was made on the coil, the special wattmeter is no longer required. A condenser is simply connected into the circuit as shown in Fig. 5 of the paper. The screened enclosure is swung over the unit operating as it latches the safety switch. The current is set at the correct value for the unit on test and the watts loss read on the meter, a standard Westinghouse wattmeter. Assume a typical case of a total of 32 watts. By reference to a calibration curve, the loss in the inductance is determined which is of the order of 20 watts. To this is added the meter losses which in this case would be 3 watts. The loss in the condenser then is $32-(20+3)=9$ watts or 0.45 per cent, since the unit is measured at two kv-a. It might be of interest to note that several thousand pounds of copper were required to build a two kv-a. 2300-volt inductance with a loss of only 20 to 25 watts. This, of course, was an air core construction.

I would like to ask Mr. Stacy why the condenser did not operate without reactors on a short feeder. I am wondering if the difficulty was that of not obtaining the power factor expected, or failure of the insulation in the condenser due to heating of harmonic currents.

In applying reactors with static condensers it should be noted that a given reactor is suitable for only one value of condenser and that either the condenser capacity cannot be changed freely or the reactor must be changed by means of taps every time the kv-a. of the condenser is changed.

The writer has observed the performance of many condensers where no reactors were used and in no case has the use of a reactor been found necessary or even desirable. In all cases the power factor was that to be expected, as well as the currents in the condenser leads. It is quite possible that under certain conditions reactors may be indispensible. It does not seem necessary to make a general use of them. In fact their use should be avoided wherever possible. We are adding condenser capacity to correct for electromagnetic fields. If we add reactors we must add still more condenser kv-a. The type of condensers described above would not be damaged under the worst conditions by harmonic current. They have been used to pass a high 500-cycle superimposed current when operating at rated 60-cycle voltage, in special applications.

In reply to Mr. Robinson's question regarding d-c. application, I wish to say that we have found it desirable to work at higher stresses on d-c. than on a-c. Condensers for a-c. service are rated for commercial lines. The voltage may go up to fairly large values at times. Thus for a-c. service a large factor of safety is incorporated in the design. In addition, the critical stress for d-c. is much higher than for a-c.

For d-c. service the problem is different. Since there are no standardized d-c. voltages for radio broadcasting, the condenser can only be rated for absolutely maximum. The user must take into account poor voltage regulation which varies with every outfit, over a very broad range. A condenser for 3500 farads direct current is therefore maximum rated. If there is a large ripple in the direct current the peak value should be within the d-c. rating. All d-c. conde nsers are tested at twice d-c. operating voltage for one minute. It is intended that the rating should not be exceeded in service by surges, etc.

The d-c. working stress varies between 275 and 460 volts per mil, depending on the rating. As the voltage rating is increased, the working stress is reduced to allow for less uniform voltage distribution through the material.

EFFECT OF TIME AND FREQUENCY ON INSULATION TESTS OF TRANSFORMERS[1] (Montsinger) and INSULATION TESTS OF TRANSFORMERS AS INFLUENCED BY TIME AND FREQUENCY[2] (Vogel)

Philadelphia, Pa., February 7, 1924

Vladimir Karapetoff: For several years previous to his death, Dr. Steinmetz talked from time to time about third-class conductors and pyroelectric effects, and I often asked myself, why this interest in the third-class conductors. I did not see the point until the appearance of his paper in the "*Electrical World*," giving the so-called *pyroelectric theory of breakdown of insulation.* At the same time, but independently from Dr. Steinmetz, Dr. Willy K. Wagner in Germany was working on the same subject. He came to this country on a visit in 1922 and read a paper (printed in the 1922 A. I. E. E. Transactions) which for a long time will remain a classic on the subject. In other words, where Dr. Steinmetz only had time to go into the theory qualitatively, Dr. Wagner also gave us at least a beginning of a mathematical theory of the breakdown of solid dielectric.

The principle underlying this theory is as follows: Let there be a layer of solid dielectric between two metal electrodes and let this layer be subjected to a d-c. voltage. Let us also assume that somewhere in this dielectric there is a weak filament (or a succession of weak spots which later form a weak filament) along which a breakdown takes place. According to the pyroelectric theory, not only the whole dielectric has a negative temperature-resistance coefficient (which we know only too well to be true), but this weak filament in particular has a very marked negative temperature coefficient, so that the conductivity of this filament or thread increases as the temperature goes up. In this you see immediately an element of instability, which should lead to a breakdown. Being a weaker filament, in the sense of having initially a somewhat higher conductivity than the rest of the material, this filament conducts in proportion more current than the rest of the sheet and consequently becomes warmer than the rest. But, by supposition, when it becomes warmer, its conductivity increases; therefore, it begins to draw more current. Its conductivity again goes up, and so forth. Thus, naturally, a conductor of this kind, applied at a source of sufficient high potential, must ultimately take an infinitely great current. Before it does so, the material is carbonized, or otherwise changes, and we have a breakdown. In other words, according to both Dr. Wagner and Dr. Steinmetz, we have here a pure thermal or pyroelectric effect. There is no mysterious "breakdown," no critical voltage in that sense; it is simply a matter of heating a filament to a point where it becomes a piece of carbon.

Now, if that be so, then by using a source of constant current rather than a constant voltage, we should be able to go beyond the "limit" and yet not break a sample down. Dr. Wagner used wooden blocks for electrodes, with fibers in the direction of the current. Dr. Steinmetz used a Nernst filament, that is, a piece of material of very marked negative temperature coefficient. They both proved that you can go beyond the critical value of the current, but because there isn't enough voltage to cause an infinite current the material can be cooled again and it will be just as good as before, showing that there is no "electric breakdown" but only a thermal effect.

Perhaps it is a one-sided theory; perhaps the theory is only partly true; perhaps there are other factors to be considered. But if this theory be true at least in part, certain mathematical relations follow immediately. You can write a differential equation between the applied voltage and the temperature, and this equation, integrated, gives a function which a material ought to obey. Dr. Wagner uses three different conduction

1. A. I. E. E. Journal, Vol. XLIII, February, p. 145.
2. A. I. E. E. Journal, Vol. XLIII, July, p. 627.

functions to start with, and carries his computations through, correctly stating that we haven't enough experimental evidence as yet to decide which of the three functions is the best. We at Cornell took still another function and also carried the mathematical deductions through to show that there are also other possibilities and that the pyroelectric theory is very elastic in its very foundation.

The papers under discussion interested me greatly as offering new material for a confirmation or a modification of the pyroelectric theory. Dr. Wagner has computed the theoretical effect of the frequency upon the breakdown, and also the effect of the time of application. No matter which of his three functions he takes, the effect of the frequency is linear. If you plot the breakdown voltage against the frequency as abscissa, you obtain a slanted straight line because as the frequency increases, the dielectric loss also increases. It heats the slab and thus prevents more heat from being radiated from the filament sidewise.

Referring first to Figure 16 in Mr. Montsinger's paper, he obtains a straight line when he plots his voltage, not to cycles but to log. of 1 over cycles. This being a straight line, plotting it to the frequency would give a curve of the shape of a hyperbola. So I thought at first that Wagner's theory was inadequate in this case. However, you will notice that the point corresponding to 25 cycles is rather uncertain, and it is the 25-cycle point that makes the curve go up so much. By changing it a little, we can get a much closer approximation to a straight line. If we take the data given in Fig. 15 (I selected the data for four layers) and replot them to frequency, we obtain an almost straight line, except for 25 cycles.. Taking, furthermore, the first page of Mr. Vogel's paper and combining the ultimate voltages there for different frequencies, I also get practically a straight line. So that on the whole, I see in the new data a confirmation rather than a contradiction of Wagner's theory. I hope that from now on we shall not only multiply experimental data, but also analyse them so as to see whether they confirm or contradict the pyroelectric theory.

Everett S. Lee: Here we have an example of two investigations, made in different places by different men, both to answer the same question, and although they got together, I take it, before they started to make their tests, I am quite sure that they viewed their conclusions in finality before getting together, and if you will read both papers and go through them very carefully, you will note that they are remarkably consistent for this kind of work. One reason is because of the fact that the tests were taken under essentially the same conditions.

In that regard I would call to your attention the fact that at the present time the American Society for Testing Materials is doing quite a bit of work to try to standardize tests on electrical insulating materials. That is of interest to all of you, and if you will place yourself in the position of the man who has to make those tests and go to the standards of our own Institute to try to find out how those tests should be made, or what time should be used in making the tests, etc., you will find nothing there. In other words, it is a branch of the art that has not been taken up and put in the standards of our Institute. So that the American Society for Testing Materials is doing that work, and a considerable amount of the information that Mr. Montsinger and Mr. Vogel compiled has been used in allowing us, in turn, to standardize work requiring the determination of the dielectric strength of insulating materials.

I call your attention particularly to the fact that the curve between dielectric strength and time of voltage application is not a straight line and that tests made for dielectric strength of insulating materials, where the value of time may be low, may bring you on such a portion of the curve that a small difference in time will mean a large difference in dielectric strength; so that if an observer in New York compares some data with an observer some miles distant, those two observers may find that they have different results if they have not taken this into account. So I feel that in these two papers we have been helped considerably in that phase of the work.

Regarding Professor Karapetoff's discussion, we too noted, as he brought out, a tendency for that curve to bend upward at the lower frequencies, and I might state that Dr. Steinmetz had in mind making tests very carefully in the range of 25 cycles down to zero, and that portion of the work which he was carrying on is being continued, and we hope that it will throw additional light upon this particular phase of the question.

I hope that all of you have taken occasion to read the article entitled, "High Voltage Insulation," by Dr. Steinmetz and Mr. J. LeRoy Hayden, which appeared in the January issue of the Journal, because that paper summarizes practically in toto the results of the work which Dr. Steinmetz had carried on in the last few years in his investigation of the mechanism of breakdown of insulating materials.

V. M. Montsinger: I am very glad to have Professor Karapetoff discuss this question from the pyro-electric theory standpoint. I have read very carefully both Dr. Wagner's and Dr. Steinmetz' articles on the pyro-electric theory of failure of insulation. Space, however, did not permit of making comparisons between my results and the formulas given by Dr. Wagner in the way it should be done. Furthermore, additional data on the strength at the lower frequencies, that is, from about 25 cycles down to 0 cycles (direct current) are needed before drawing any definite conclusions as to whether the data substantiates or refutes Dr. Wagner's formula which shows that the strength is a linear function of the frequency. From what tests I have made and according to Mr. Vogel's tests made on single sheets of pressboard (fullerboard) the linear function does not seem to hold very well. For example, taking the data from Mr. Vogel's curves, Figs. 1 to 8 inclusive, covering tests made at 60, 140, 220 and 350 cycles and at 25 deg. and 75 deg. cent. and plotting the 20-sec. kv. values (which points appear to be the most reliable) against the reciprocal of the frequencies, we get practically straight lines on log-log paper, the slopes of the lines being 0.146 at 25 deg. cent. and 0.136 at 75 deg. cent. The average slope of the two lines is approximately 0.141 as against the value of 0.137 which I obtained. From the available data, the indications are that the dielectric strength of solid insulation is not strictly a linear function of the frequency. Further work along this line is being done and it is hoped that enough additional data can be secured to settle this point one way or another.

SHORT CIRCUITS OF ALTERNATING-CURRENT GENERATORS[1]

(Laffoon)

Philadelphia, Pa., February 7, 1924

P. L. Alger: I have only one comment to make, and that is to remark that I believe the effect of saturation is quite an important one, especially in the application of the same type of theory to the initial currents of induction motors when they are thrown on the line in starting. Saturation makes the actual reactance of the machine much lower than it is when measured under normal conditions, and consequently, the initial current rush is much higher than might be expected, as in 25-cycle transformers, for example, where the ordinary flux is so high as to make the current rush saturate the iron very materially.

I believe that Professor Lyon's A. I. E. E. paper about a year ago, gave a very complete mathematical theory of the subject, taking into account both the resistance or decay effect and the displacement effect, but he did not allow for saturation, and that appears to me to be the most important factor to be added to the theory of this subject.

R. E. Doherty: As Mr. Laffoon has said, the increase in the size of generators and the importance of short-circuit problems in generating and distribution systems makes it important and very desirable that this matter be reviewed at intervals so that

1. A. I. E. E. Journal, Vol. XLIII, December, p. 1142.

the engineers can become at least somewhat familiar with what happens in generators when short circuit occurs.

I think that any one who has gone over this paper will agree that in presenting it from the physical viewpoint the subject is ably handled and an insight given to the phenomena of short circuit in synchronous machines.

I should like to call attention, in a friendly way, to a bit of interesting, if unimportant history. In papers read in 1918, and also in 1920 I made a mistake. I stated the constant linkage theorem which Mr. Laffoon again presents to you, and he makes the same mistake. I said that this theorem follows from Lenz's law. Now, as Professor Karapetoff pointed out in discussing my paper in '19 and '20 the theorem does not follow from Lenz's law. It can be shown, however, that the theorem is perfectly sound. I have given such a proof, based on classical differential equations, in a paper, "A Simplified Method of Analyzing Short-Circuit Problems," at the Swampscott Convention last year.

R. F. Franklin: Expressions for the initial short-circuit current can be derived in a very simple manner by a direct translation of the constant-linkage theorem into mathematics. This method makes it unnecessary to separate the field current into two components as done in the paper.

The linkage theorem, as previously stated by Mr. Doherty is,[2] "*If the resistance of a closed circuit is zero, then the algebraic sum of the magnetic linkages of the circuit must remain constant.*" Take the first case considered, namely, that of the short circuit of a single-phase generator without damper winding. There are only two circuits involved, the field circuit and the armature circuit. Let i_1' and i_a be the instantaneous values of the currents in these two circuits. Then the linkages of the field circuit due to the field current are equal to

$$i_1' L_1$$

and the linkages of the field circuit due to current in the armature circuit are

$$i_a M_{1a}$$

Applying the linkage theorem,

$$i_1' L_1 + i_a M_{1a} = \Omega_1 \qquad (\mathbf{a})$$

where Ω_1 is a constant giving the flux linkages of the field circuit at the instant of short circuit. In a similar manner applying the linkage theorem to the armature circuit,

$$i_a L_a + i_1' M_{a1} = \Omega_a \qquad (\mathbf{b})$$

where Ω_a is the linkages of the armature circuit at the instant of short circuit. We thus have two equations involving the currents i_1' and i_a which when solved simultaneously give,

$$i_a = \frac{\Omega_a - \Omega_1 \dfrac{M_{1a}}{L_1}}{L_a - \dfrac{M_{1a}^2}{L_1}} \qquad (\mathbf{c})$$

and

$$i_1' = \frac{\Omega_1 \dfrac{L_a}{L_1} - \Omega_a \dfrac{M_{1a}}{L_1}}{L_a - \dfrac{M_{1a}^2}{L_1}} \qquad (\mathbf{d})$$

This method can be used with equal facility for the calculation of the short circuit currents for any winding connection.

It can readily be shown that equations (**c**) and (**d**) correspond to (**13**) and (**14**) except that (**d**) is the expression for the total field current instead of the induced component as in (**14**). Thus, in equation (**c**) Ω_a is the flux linkages of the armature circuit at the instant of short circuit and $\Omega_1 \dfrac{M_{1a}}{L_1}$ the flux linkages of the armature circuit due to the field circuit for any rotor position after short circuit. Hence the numerator is the change in armature linkages produced by the field circuit due to rotation. The denominator has been defined in the paper as "the coefficient of equivalent leakage self-induction of the armature circuit." Also (**d**) can be written in the form

$$i_1' = I_1 - \frac{M_{1a}}{L_1}\left(\frac{\Omega_a - \Omega_1 \dfrac{M_{1a}}{L_1}}{L_a - \dfrac{M_{1a}^2}{L_1}}\right)$$

or

$$i_1' = I_1 - \frac{M_{1a}}{L_1} i_a \qquad (\mathbf{e})$$

The two components of (**e**) are the d-c. and a-c. components of the field current respectively, the latter component being the same as (**14**) in the paper.

The inductance coefficients vary with the rotor position as shown in Figs. 6, 7 and 8, so that the current in the two circuits can be calculated for any rotor position by substituting values from the curves of these figures in (**c**) and (**d**) in the manner used by Mr. Laffoon. However, it is easier to express them as trigonometric functions and substitute these functions in (**c**) and (**d**). It is then necessary to calculate only the maximum and minimum values of the inductance coefficients. For instance, the mutual coefficient M_{1a} (Fig. 7) can be expressed as

$$M_{1a} = M_0 \cos \alpha$$

where M_0 is the maximum value of mutual inductance between armature and field circuits. The coefficient L_a (Fig. 8) can likewise be expressed as a function of α. However, the effect of saturation in this coefficient on the resultant short-circuit current is so slight that for all practical purposes L_a can be assumed constant.

I used this method two or three years ago for the calculation of the short-circuit currents for all cases given in Table I. The results I obtained do not check the values in the table. Thus for all three, 3-phase short-circuit conditions, cases 8, 9 and 10, I obtained the same maximum peak value of armature current for constant conductors per inch; and for the single-phase condition, case 1. 1.5 times the current for the three-phase conditions. For the other cases the ratio to three-phase values I obtained are slightly less than those given in the table.

On page 3 the statement is made that, "It is well known from the laws of physics that the mutual-induction coefficients of two inductively coupled circuits is the same for either circuit with respect to the other." This statement, while correct for the condition of no saturation, should be more accurately stated since it is not true when saturation is involved.

N. S. Diamant: I am very glad to note that Mr. Laffoon in his paper makes a free use of the conceptions of the four kinds of "Inductance;" it is gratifying also that he is consistent and employs the usual terminology as given in detail by Boucherot in his excellent paper presented at the International Congress in 1911.

In my paper on "Calculation of Sudden Short Circuit Phenomena of Alternators" presented in San Francisco in 1915, I did not feel that I could make free use of these ideas as they seemed rather novel; though they were by no means new. Briefly we have: (1) the self-inductance L. (2) the leakage inductance L (3) the mutual inductance M and (4) the total leakage inductance reduced to the armature or field; this is designated by Laffoon as N_a or N_f and in my several papers and discussions I have used the symbol λ. I am calling attention to these various coefficients of inductance because there has been and there is considerable confusion on the subject. (See Discussion of Doherty and Shirley's paper in the A. I. E. E. TRANS. for 1918). From a study of transient phenomena and also from the study of the ordinary transformer we learn that the amount of current and the rate of decay of current depends not on L but on the total leakage inductance λ or N as is indicated in the paper.

2. JOURNAL A. I. E. E., October, 1923, p. 1021.

The simplest physical conception of sudden short circuits, it seems to me is as follows: Consider a two-phase generator having no mutual induction between phases A and B. Just before short circuit there is a certain flux in phase A, say ϕ_a; this dies down to practically zero at the end of the short circuit.

Thus the flux in phase A during short circuit is $\phi_a \, \epsilon^{\frac{r_a}{\lambda_a} t}$ where r_a = armature resistance λ_a = total armature leakage inductance and t = time counted from the instant of short circuit. Similarly, for phase B we have $\phi_b \, \epsilon^{\frac{r_a}{\lambda_a} t}$. Now, $\phi_a = M \, I_f \cos \omega \, t_1$ where M = mutual inductance between field and armature. I_f = field current before short circuit. With reference to the field circuit we have:

ϕ_n = normal flux in the field before short circuit.

ϕ_{psh} = flux in the field at the end of short circuit; *i. e.*, flux in the field during permanent or sustained short circuit.

$\phi_{psh} + (\phi_n - \phi_{psh}) \, \epsilon^{-\frac{r_f}{\lambda_f} t}$ = field flux at any instant during short circuit.

Now, returning to Mr. Laffoon's paper we can say that

$$\phi_a \, \epsilon^{-\frac{r_a}{\lambda_a} t} = \text{flux in phase } A \text{ during short circuit.}$$
$$= M \, i_f \cos (\omega \, t + \omega \, t_1) + L_a \, i_a$$

$$\phi_{psh} + (\phi_n - \phi_{psh}) \, \epsilon^{-\frac{r_f}{\lambda_f} t} = \text{flux in field during short circuit.}$$
$$= M \, i_a \cos \omega \, (t + t_1) + L_f \, i_f + M \, i_b \sin \omega \, (t + t_1)$$

For phase B we shall have an expression similar to the one given for phase A. These equations are very simple and they are given in a graphical form in the paper, except that the attenuation factors are entirely omitted. To obtain the armature or field current it is necessary to solve the whole set of equations, and that part may be termed mathematical. Let me repeat that the solution of the equations just given may be mathematical but the analysis and physical interpretation of each equation are very simple. In fact, I think simpler and certainly more complete than that given by the author. It is not necessary to give an extended discussion of the simple physical meaning of the equations as that has already been done. See TRANS. A. I. E. E., 1915; *Electrical World* May 18; June 1; June 29, 1918. Mr. Laffoon uses the conception of a circuit without resistance; this was also used by Doherty and Shirley in 1918. Is it necessary to make this assumption, which is not easy to understand? Suppose the flux changes from ϕ_1 to ϕ_2; the e. m. f. generated by this change will be $\dfrac{(\phi_1 - \phi_2)}{t}$ and this transient e. m. f. will produce a quantity of electricity $q = i \, t$, where i is a decaying direct current. Thus a direct current is produced in phase A of the armature provided that phase A enclosed an amount of flux ϕ_1 at the instant of short circuit. If the position of the phase A is such that it encloses no flux at the instant of short circuit then there will be no direct current produced in it.

In this way all the phenomena can be explained without recourse to a *circuit without resistance*. Another advantage of this is that it involves an old well-known principle, which is used to determine the apparent resistance of a ballistic galvanometer on closed circuit. I would like to ask if Mr. Laffoon has made use of this principle and how and why did he resort to the conception of the circuit without resistance.

In Table I values for the maximum possible armature currents are given. These do not include the attenuation factor of either the armature or the field, and nothing is said about their effect. In all my work I had found that the effect of these was not negligible; I would like to have Mr. Laffoon's opinion on this since he has accumulated a great deal of experimental data on the subject.

It is stated by the author that damper or amortisseur windings have no effect on the armature current. I would like to know if damper windings have any effect on the attenuation factor, that is, on the rate of decay of the armature current. To what extent do test results check with the approximate and more accurate equations given by Boucherot for alternators with and without damper windings? To what extent do the values for i_{omax} given in Table I agree with the expressions given by Boucherot?

C. M. Laffoon: In presenting the analysis of the short-circuit currents of alternating current generators, the mathematical derivation of the general relations was not given on account of the fact that this phase of the problem has already been given considerable consideration by other writers. It was thought that the presentation of the physical conception of the phenomena would facilitate the interpretation of the actual results and mathematical relations by an appreciable number of engineers. That is, the physical or graphical analysis was intended to be considered as a supplement to the mathematical treatment rather than as a substitute for it.

Mr. Doherty's criticism in regard to the writer's statement that the constant linkage theorem was based on Lenz's law is well taken. The statement of the constant linkage theorem as given by the writer follows from Lenz's and Kirchhoff's Laws.

It is practically impossible to calculate the effect due to saturation on account of the complexity of the leakage flux paths and the distribution of the leakage fluxes. The effect of saturation

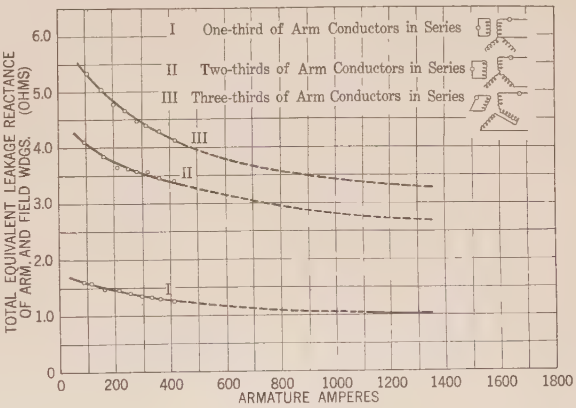

FIG. 1

is apt to be quite large when the short-circuit occurs at normal voltage, for approximately double the normal amount of flux interlinkages must traverse the leakage flux paths. The following curves show the decrease in value of the total equivalent leakage reactance coefficient of the armature and field windings with armature current for the case of a 6250-kv-a. turbo generator. These test results were obtained by locking the rotor in such position that the axis of the field winding coincided with one phase group of the armature winding, short-circuiting the field winding, and then applying alternating voltage to the armature winding.

The formulas for the maximum peak values of the armature current and the comparison ratios for the different winding combinations, which are shown in Table I of the paper, were determined on the basis that the short-circuit occurs at the instant the axis of the field winding coincides with the axis of the part of the armature winding included between two adjacent leads. All of these cases are treated in considerable detail in the original paper, and it would be necessary to know the assumed short-circuit conditions under which R. F. Franklin obtained his results before attempting to account for the discrepancies. However, at the present time sufficient reliable test data is not available to definitely confirm the relative ratios as given in Table I.

In presenting a quantitative physical conception of the short-

circuit phenomena, it seemed advisable to the writer to consider the case of an ideal generator first, and then to show the effect of the different physical constants which are present in the actual generator. The writer is famiiar with the method suggested by N. S. Diamant for determining the value of the resultant flux interlinkages of each circuit at any given time. While this method is sufficiently accurate for most cases, the actual change in flux interlinkages is quite different from that shown by a simple exponential equation. This question is considered by the writer in a second paper on the same subject, which was presented at the Northeastern Regional Meeting, at Worcester, Mass., June, 1924.

A damper winding which is located at quadrature with respect to the field winding has no effect on the magnitude of the peak values of the armature current, but it does modify the wave shape and hence affects the r. m. s. values. If part of the damper winding acts in parallel with the field winding, the maximum peak value of the armature current will be affected to the extent that the total equivalent leakage induction coeffiient of the armature winding is modified. The effect of the damper winding on the rate of decay of the armature current is given in the writer's second paper which was previously referred to.

Dr. P. Boucherot's original paper only considered the case of the single-phase, and two-phase generators; consequently sufficient data was not available for making a comparison with the results given in Table I.

ECONOMIC DEVELOPMENT OF STEP-BY-STEP AUTOMATIC TELEPHONE EQUIPMENT (Andres)

Philadelphia, Pa., February 7, 1924

G. K. Haspel (by letter): In general, only one connector group is required per 100 lines when these lines serve individual or P. B. X. subscribers, but for party-line service it has been the practise to provide as many groups of connectors per 100 lines as there are parties on the party line, that is, for two-party service, two connector groups per 100 lines are required and for four-party service, four groups.

The comparatively recently developed frequency-selecting connector which selects the ringing frequency (or other party-line station selecting feature), as well as connects to the called line, requires only one connector group per 100 lines, regardless of whether the line gives two-party, four-party or ten-party service.

It is obvious, with the regular connector method, that more connector groups will be required than line switch groups, or, in other words, the number of line switch groups will correspond to the number of hundreds of lines while the number of connector groups will correspond to the number of hundreds of possible stations.

In reducing the number of connector groups so that it corresponds to the number of groups of 100 line switches, the use of frequency-selecting connectors not only reduces the total number of connectors but in many cases also reduces the number of selectors. This saving in equipment is illustrated in the attached sketches showing trunking schemes for an exchange of 800 lines of mixed individual and party-line service.

Fig. 1 herewith shows the switching scheme for 800 lines using frequency-selecting connectors and provides for individual and party-line service up to ten parties per line. Fig. 2 shows a scheme for the same number of lines but for individual and four party service with four connector groups for each 100 lines. In the latter scheme, 32 connector groups are required, making necessary the use of second selectors between the first selectors and the connectors, which is not necessary in the frequency selecting connector scheme, since the latter has only 8 connector groups.

In Fig. 1, eight levels of the first selectors are used (the "1" and "0" levels are usually reserved for special services) but when more than eight groups of connectors are required, the introduction of intermediate selectors, with access to ten groups each becomes necessary. Thus in Fig. 2, with 32 connector groups, four groups of second selectors are required.

In the two schemes illustrated, the same number of first selectors is required in each case; 137 second selectors are required in Fig. 2, while none are required in Fig. 1; and the

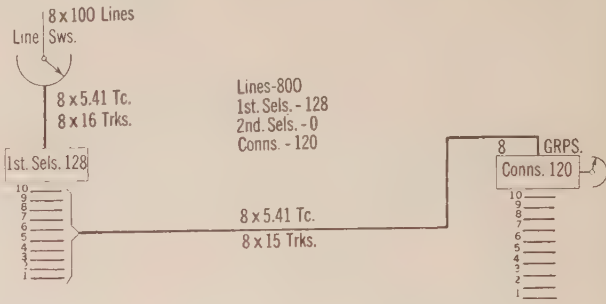

Fig. 1

number of connectors is greater in Fig. 2 because 32 smaller groups are required as against ten large groups in Fig. 1.

Not only is more equipment required for Fig. 2 but there is also an increase in the battery drain per call, of about 7%, due to the necessity of the second selector in the train of each call. The greater number of switches and associated equipment involved would also increase the maintenance costs.

Further advantages for the frequency-selecting connector scheme, when used for all services (excepting P. B. X. or trunk-

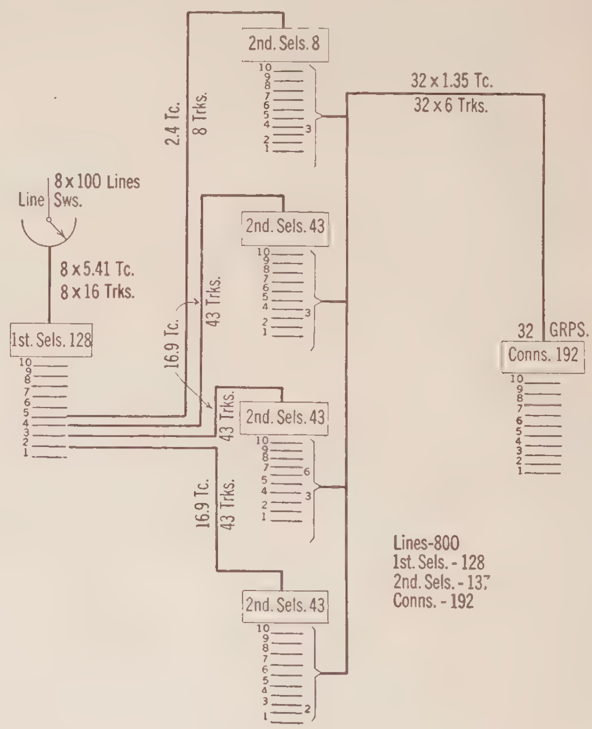

Fig. 2

hunting service), are:—the use of any line for either individual or part-line service, and by mixing these on each unit a more equal distribution of traffic may be obtained; selective ringing of extension telephones; and the possibility of changing individual to party lines without changing the directory numbers.

The principle objection to the frequency-selecting connector scheme is the difficulty of providing intercepting service for

A. I. E. E. Journal, Vol. XLII, December, p. 1309.

"dead" and changed numbers. This is accomplished by the use of frequency relays bridged across the lines on which calls are to be intercepted and, if the number of calls to be intercepted is large, the cost of the relay equipment is considerable. However, in many exchanges, this intercepting service is not considered necessary, so in such cases the objection does not apply.

With frequency-selecting connectors, each line has a possible ten directory or station numbers and, when less than ten stations assigned to a particular line, the remaining numbers are useless. This has been called a "waste of numbers," but, since no waste of equipment is involved, the loss is not a material loss, and the objection is not considered valid. Moreover, whether all the numbers are used or not, they are available for use, which gives them an actual economical value.

The frequency-selecting connectors are somewhat more expensive per switch than the regular type connectors, but this is often counter-balanced by the decrease in the amount of selectors and connectors required for the entire office or exchange, or, even if the total cost is greater, it is quite possible that the service advantages will justify the extra expense.

FUNCTION AND DESIGN OF HORNS FOR LOUD SPEAKERS[1] (Hanna and Slepian)

Philadelphia, Pa., February 7, 1924

H. Fletcher: The mathematical presentation of the design of horns is one of the best that has appeared in recent years. The equations evolved point out not only some of the criteria for good design, but show the serious limitation of the horn for producing natural reproduction. As pointed out by the authors, the applications of the equations are limited because of the assumptions involved in deducing them.

I desire to emphasize some of the results predicted by these equations and also some of the limitations in the application of them. First, I should like to discuss briefly the criteria the authors set up for good quality transmission. As they mentioned they are essentially the same as given in the paper by Mr. Martin and myself. However, I would interpret somewhat differently the things put down as responsible for the introduction of extraneous frequencies.

The so-called transients set up in the diaphragm are only present when corresponding transients are in the driving force. In the steady state they are absent; so it seems to me better to consider that the diaphragm produces a frequency distorting effect which is the same for all kinds of driving forces. This is particularly true when dealing with speech where there is an almost continuous variation in the form of the waves coming from the diaphragm.

One of the requirements given in the paper for an ideal loud speaker is that the energy radiated at each frequency be proportional to the square of the current. In practically every loud speaker the electrical impedance at the terminals varies over a wide range as the frequency varies, and consequently, maintaining a constant current does not maintain a constant energy input. So it seems to me that it would be better if this requirement were modified to read that the relation between the electrical energy absorbed to the accoustic energy radiated shall be constant for all frequencies.

Also, one of the principal points brought out in the paper is that by loading the diaphragm by making the opening into the horn small, the frequencies introduced by the non-linear characteristics of the diaphragm will be greatly reduced due to the reduced amplitude at which the diaphragm is working. I should like to call atention to the fact that this reduction in amplitude is accompanied by a corresponding increase in the pressure variation in the air chamber which may in some cases produce just as serious overloading as that due to the large diaphragm amplitude. Very frequently in ordinary conversation, the pressure amplitude is greater than 50 dynes. To reach large gatherings this amplitude must be increased at least 100 times, so that the pressure amplitude at the large end of the horn may frequently be greater than 5000 dynes. For the horns discussed in this paper then, the pressure amplitude in the small air chamber would frequently exceed 500,000 dynes or one-half atmospheric pressures. For such large amplitudes, harmonics which are from 50 to 100 per cent of the fundamental, will be created. This difficulty is overcome in the type of loud speaker used in our demonstration by using a large diaphragm and doing away with the enclosed air chamber. The magnetic system is loaded by the large mass of air in front of the diaphragm and consequently no excessively large amplitudes of either pressure or diaphragm motion exist anywhere in the system.

Equations **41** and **42** of the Appendix are important from a design standpoint. It is interesting to note that these equations predict that you cannot build a loud speaker having a horn connected to a diaphragm in the way indicated, which will have a uniform response.

For the numerical case discussed on page 3 of the paper, if I interpret the equations correctly, the power radiated at 40 cycles would be only 1/250th of that at resonance. Even for this case, the volume of the air chamber is so small that air friction is beginning to play an important part, and, as mentioned the non-linear distortion of the air chamber is beginning to be very appreciable, due to the excessive values of the air pressure. For the dimensions of the diaphragm and the air chamber given, the distance between the diaphragm and the stationary plate is less than one-fifth of a millimeter. You see, that is a very small gap in order to reach the condition that I just mentioned, that the power radiated be only 1/250th of that radiated at resonance.

This limitation imposed upon the loud speaker, as indicated by these equations, is due largely to the assumption that the diaphragm and the moving magnetic system can be represented by a single degree of freedom and it is coupled to the horn by a single air chamber. If the moving magnet and the air chambers coupling the diaphragm to the horn are composed of several members, this limitation is largely removed. It is always possible to design the driving mechanism and its coupling to any horn of known physical characteristics so that as nearly a uniform radiation at all frequencies as is desired will result. Also, having given a driving mechanism of known characteristics, it is possible theoretically to design the horn and connecting chambers so that approximately uniform radiation will result. However, when one tries to meet these requirements in a practical design, it is found that no materials available have the proper physical characteristics and it is therefore necessary to make compromises.

The discussion regarding exponential horns is very interesting and confirms in a very beautiful way some of the earlier work along this line.

I might call attention to the fact that horns having cross-sections which vary exponentially are not new. The horns used in the public address system and which have been used during this convention are so designed and have been used throughout the country during the past two or three years.

Prof. V. Karapetoff: This problem of horns is a "house-on-fire" problem, in the sense that loud speakers are now being manufactured by the thousand, and while they are being manufactured and sold, we are trying to find out their fundamental theory.

At different times this Institute harbored various orphan branches of natural sciences. While we are harboring accoustics and acoustical papers, I want to be sure that we are carrying on this branch of science in the right way. To me, the right way is that of physics, and it is in this respect that I regret that the authors of this otherwise excellent paper do not even refer to the previous work of physicists on horns.

It was the privilege of this Institute, from the year 1918 to 1922, to have among its fellows one of the greatest physicists of this country—Dr. Arthur Gordon Webster—and one of his great contributions to physics was a theory of horns.

1. A. I. E. E. Journal, Vol. XLIII, March, p. 250.

It was my privilege in 1918 to spend a day with Dr. Webster. He showed me two horns, both shaped like the flare of a trombone—one made out of brass; the other made out of plaster of paris. He said: "I'll bet you couldn't tell the sound of one from the other." I was offended, but accepted the challenge—and he won. At that time he said: "I worked out a complete mathematical theory of horns and I checked it with my phone and phonometer"—two wonderful instruments that he had developed—"and it checks very well." Later I saw his papers in the 1919 and 1920 *Proceedings* of the National Academy of Sciences—two classical papers—and I sincerely hope that the authors will at least add a reference to these papers in a footnote, for the benefit of further investigators.

While it is true that a horn has the function of an antenna, are we sure that the horn shape is the best possible shape for an àcoustic antenna? Consider an expensive violin or the cello. Either of these is a complicated physical body, with at least four hundred years of development by great masters behind it. The response of these instruments is perfect within a wide range of frequencies. I hope that someone interested in acoustic antennas will try to couple a diaphragm with a violin body and see what results may be obtained.

S. Boyajian: The authors have clearly brought out the difference in the characteristics of conical and exponential horns, namely that the conical horn intensifies the higher frequencies more than the lower frequencies, while the exponential horn affects them all equally. I would like to ask the opinion of the authors about a possible application of the conical horn to phonographic work. A phonographic record is not true to original; what it lacks is not volume but intelligibility which indicates that the higher harmonics have been recorded much weaker than lower harmonics. Would it not be a good thing, therefore, to use a conical horn so as to intensify the higher harmonics more than the lower harmonics, approaching thereby the original ratio of amplitudes of various harmonics? In the leading types of phonographs with internal horns, the horns consist of a few conical sections. All of the sections do not have the same angle, and the complete horn, therefore, is an intermediate product between the conical and the exponential type, probably nearer the former than the latter. It appears, therefore, that the phonograph manufacturers have (either knowingly or unknowingly) selected a construction which is more desirable for phonograph reproduction than the theoretical exponential horn.

A. Nyman: The paper by Dr. Slepian and Mr. Hanna is a very good and novel treatment of the subject. It gives a mathematical analysis of the subject and proves by experiment that this analysis is correct.

I believe that this same treatment of loud speakers could be extended farther. Two of the essentials of the loud speakers were mentioned: One, that the loudness at different frequencies should be constant; and the other one, I believe, the intelligibility. With regard to intelligibility, there is a quality in loud speakers that has been very little appreciated so far. I call that quality persistance. It consists of the existence of sound emerging from the horn after the applied electrical vibration has ceased in the loud speaker.

Some time ago I was able to conduct some very simple experiments by mechanically listening to a loud speaker after cutting off the applied current, and I found that at certain frequencies, there was an aparent presence of sound.

I believe that a large amount of distortion in the loud speakers is due to this one cause. Quite recently a loud speaker was brought to my attention where this was remedied to a large extent and apparently clarified the sound quite considerably. I believe that similar treatment, as that which has been exercised so far by Dr. Slepian and Mr. Hanna, could be applied to this one quality.

Another quality is directive action of the horn. Everybody is aware that there is such a directive action, and I believe that by proper design of the horn, it could be spread out so that every direction from the horn would receive the same amount of sound.

E. W. Kellogg (by letter): As a means of conversion of electrical into sound energy the loud speaker is extremely inefficient, and one of the chief reasons is the low transfer of energy from the diaphragm to the air. The paper under discussion describes an effort to obtain an approximate impedance fit between the air column and the diaphragm. It would be interesting to know whether it has been possible in practise to obtain very much higher sensitivity in this way than has been obtained with the usual horn proportions.

Another question of practical interest is whether it has been found possible to coil up the horn without impairing its action.

In section II a certain volume is called for in the cavity in front of the diaphragm. The effect of a cavity any larger than necessary at this point would be to reduce the output of some of the highest frequencies. Since it is not evident that such a thing is desirable, this requirement is a little puzzling. Does it not come about from having specified that the output at both ω_2 and ω_1 shall be $\frac{1}{n}$ times that at resonance The resonant frequency 1000 is slightly above the geometrical mean of the upper and lower limits 4000 and 200. Therefore without the cavity, the output at 4000 cycles comes out a little greater than at 200 cycles, and to equalize the two an air cushion is introduced. Would it not be simpler and more satisfactory to impose the condition that at *neither* of the extreme frequencies shall the output be less than $\frac{1}{n}$ times that at resonance? I am asking this question in the interest of simplifying the calculations rather than for its bearing on actual design, for the volume of the cavity as given in the illustrative example is about as small as it would be practical to make it. I would expect that any cavity volume less than that in a quarter wave length of the tube would have very slight effect.

At the end of the paper is a statement that reflections decrease with decrease of B. This is misleading. The curves of Fig. 16 show that for a given value of r_1 and ω, the larger the value of B, the less the reflection. For example, take $r_1 = 20$ centimeters, $B = 0.05$ and $\omega = 5000$, giving $r_1 B = 1$ and $\frac{\omega}{B} = 10 \times 10^4$. The reflection as shown by the top curves is 8 per cent. Now if B is given the value 0.1, $r_1 B$ becomes 2, and $\frac{\omega}{B}$ becomes 5×10^4, for which the reflection as shown on the lowest curve is about 3 per cent.

A word of interpretation of Fig. 16 may be of interest. Each curve represents a certain shape of horn, without saying anything as to its absolute size. For example $r_1 = \frac{2}{B}$, or $r_1 B = 2$, represents a horn ending with a flare angle of 45 deg. to the axis. If we take two such horns one just twice the size of the other, the larger horn will react to sound waves of a certain length exactly as the smaller one does to sound waves of half the length. The horizontal scale might equally well have been made to read "diameter of bell divided by wave length."

An interesting analogy to an exponential horn, is an electrical transmission line in which starting from one end, the inductanec decreases exponentially with distance, and the shunt capacity increases so that their product remains constant. The propagation equations for such a line take the identical form shown in Appendix III of the paper. Above a certain frequency waves are propagated along such a line very much as they are over a

uniform line, except that the velocity is higher than for a uniform line with the same value of the product $L\,C$. Such a tapered line provides a possible substitute for a transformer for fitting two unequal impedances together. The telephone companies have employed this principle in the form of tapered loading to prevent excessive reflection losses at junctions of loaded and unloaded lines. A horn performs the same function of providing a better impedance fit between the relatively stiff, heavy diaphragm and the very light, or low-impedance air in free space. The equations for the electrical line show an infinite velocity at a certain critical frequency and at all frequencies below this.

The writers express some doubt as to the validity of the equations in Appendix III for frequencies for which the velocity of propagation becomes infinite. I think the difficulty lies, not in the approximations mentioned, but in our understanding of the term "infinite velocity" and in the assumption of zero reflection. In transmission calculations we say that the velocity of propagation is equal to $2\pi f$ divided by the quantity that expresses the change of phase per unit length of line. Now it is quite possible to have the current in phase at all points along a line, for example in a low-loss line less than a quarter-wave-length long, and open-circuited at the far end. A quarter-wave-length organ pipe also has zero phase difference from point to point. This is true only of steady-state conditions and does not mean that energy is transmitted at infinite velocity. You notice that in the examples I have mentioned, no power is being transmitted to the far end. As soon as power is taken from the end of the line a phase shift appears. This is true also of the horn. The equations given are for a zero-loss line infinitely long, and they show that such a line has a zero-power-factor impedance, or transfers no power, for frequencies below the critical value. Abover the critical frequency, absorption of power at the bell end of the horn is what is required to prevent reflections, and the equations for simple outward propagation represent a possible condition. Below the critical frequency, an infinite line can be simulated only by a zero-power-factor terminating impedance, which is not the condition under which a horn works. Therefore the complete solution, using both values of propagation constant, must be retained for frequencies below the critical value. It will then appear that when power is radiated from the bell, there is a progressive shift of phase along the horn.

L. P. Rundle (by letter): In nearly all of the better grades of radio loud-speaker horns there is at least one right-angle bend; in others there are two and in still others a circle and a half, *i. e.*, six right-angle bends. In this paper no mention is made of bends, what effect they have on the acoustics of the horn or how they should be designed. I should like to know the mathematical treatment and design for bends and curves in the horn. Again no mention is made of the effect of different materials for horns, or the proper thickness in relation to the other distribution of the material and this is an important item.

No mathematical and physical treatment is given which has to do with the tone color and quality and what, for instance, will make some sound-radiating devices give a sound that is full, rich, and mellow. This is very noticeable in phonographs, as well as loud speakers for radio work, For instance, it is easily noticeable in comparing a Victor and a Brunswick phonograph, in which both have five right angle bends from diaphragm to the end of the horn but which play the same record with a considerable difference in tone quality. I have noticed the same difference in different makes of loud speakers, and to a less extent in the loud speakers of the same make connected to the same receiver set. Now what makes this difference in tone quality?

Another thing that is quite noticeable in some of the loud speakers is that the sound appears to come from the far end of a long hall, which may be due to a sound-image effect and which is a great detriment to any sound-radiating device. How can this be taken care of in the design of horns?

The papers says nothing about the principle of reflected tone or sound, which is one of the principal points in the advertisements of one maker of a very pleasing loud talker. I would like to know if the authors have any data on the design of this type of loud speaker and how it compares with the exponential design of horns.

The equation giving V_o (the volume of the air behind the diaphram) does not tell anything in regard to the shape of that air volume. It may be very thin at the outer edge of the diaphragm. This brings up another point that was not treated in the paper, namely, the limiting size of the throat of the horn and the closeness of the diaphragm backing when friction would cause severe losses. I should like to know if the authors have any data on these points, and if they have made any tests to determine the coefficient of air friction for various materials such as mica, iron, aluminum, fibre, wood, etc. If so, what are these coefficients? It would be interesting to know if the authors have made any experiments on a horn such as coating the inside with various materials such as oils, waxes, graphite, etc., to see what effect it had on the sound-radiating qualities of the horn.

In regard to the shape of the air volume behind the diaphragm of a phonograph, I have found that the shape of that volume is quite important in that it has considerable to do with the sound intensity and somewhat with the quality, this latter evidently being due to the reflections of sound from diaphragm to backing and vice versa, as well as the echoes from rim to rim of the sound box. It seems quite possible that in a sound box of poor design these things will cause stray noises and blasts that blur the quality of tone at certain frequencies.

In the example worked out, N is taken as 10. I should like to know what determines the best value of N to use in the design of a given horn.

I should like to know how the power radiated at resonance, $W\,r = 2\pi \times 1000$, is determined in designing a new horn.

The paper makes no mention of the shape of the diaphragm or the material. Some loud speakers have a corrugated diaphragm, some a concave or arched construction with corresponding curves at the back of the diaphragm and others a mica diaphragm. I should like to know from the authors if they have made any experiments on diaphragms and what effect the size, thickness, shape and material has on the size and shape of V_o and the force required to set the diaphragm in vibration. A mathematical treatment of the physics of vibrating materials of which diaphragms are made would be a proper subject to go with this horn, since the design of the horn is intimately linked with the characteristics of the diaphragm which it loads.

John Minton (by letter): The work which Dr. Slepian and Mr. Hanna have presented is a valuable contribution to existing literature on the subject of horns. Their results apply almost entirely to horns of infinite length, in which case we do not need to consider reflection from the end of the horn. In this case the radiated sound energy can be calculated readily, provided certain simplifying assumptions are made.

Independently of the work of the authors Dr. Goldsmith and I have been engaged in a rather extensive experimental and theoretical study of horns of finite lengths and in a forthcoming paper we shall present a review of certain phases of our work.

In connection with the paper which has just been given, I desire to discuss certain phases of it, particularly those treated in Appendix III. Inasmuch as the publications on this subject are rather meagre, it is desirable, it seems to me, to call attention to certain of these which are of fundamental importance to this subject. This is particularly true because the authors apparently have not made use of such publications and they have, therefore, duplicated much that has been published for some time.

Lord Rayleigh, "Theory of Sound" Volume II, page 158, gave the equations for the pressure, velocity and energy radia-

tion in a straight tube of unlimited length. His three equations for these quantities are respectively:

$$\rho \frac{d\,\phi}{d\,t} = -\frac{\partial a A}{2\,\sigma} \cos k\,(a\,t - x) \tag{1}$$

$$\sigma \frac{d\,\phi}{d\,x} = \frac{1}{2}\,A \cos k\,(a\,t - x) \tag{2}$$

$$P = \frac{\rho\,a\,A^2}{2\,\sigma} \tag{3}$$

where ρ = air density, $k = 2\,\pi$ divided by the wave length (λ), a = velocity of sound, σ = cross sectional area of tube, ϕ = velocity potential and A determines the strength of the source of sound. The source of sound is considered placed at one end of the tube which is closed at the end adjacent to the source. The first two equations show that the pressure and velocity are in phase. The third equation shows that the sound radiation along the tube is inversely proportional to the area of the tube and constant with, or independent of the frequency.

Lord Rayleigh's equations, "Theory of Sound" volume II, page 113, for the straight conical horns in which the source of sound is located at the vertex are as follows:

$$\rho \frac{d\,\phi}{d\,t} = -\frac{\rho\,k\,a\,A}{\omega\,r} \sin k\,(a\,t - r) \tag{4}$$

$$\omega\,r^2 \frac{d\,\phi}{d\,r} = A\,[\cos k\,(a\,t - r) - k\,r \sin k\,(a\,t - r)] \tag{5}$$

$$P = \frac{\rho\,k^2\,a\,A^2}{2\,\omega} \tag{6}$$

The additional factors involved are defined as follows: r = the radial distance and ω = the solid angle of the cone. The first two equations show that the velocity leads the pressure by an angle whose cosine is $\frac{k\,r}{\sqrt{1 + k^2\,r^2}}$. That is:

$$\cos\theta = \frac{k\,r}{\sqrt{1 + k^2\,r^2}} \tag{7}$$

When the frequency is very high or when r becomes large the expression for $\cos\theta$ becomes essentially unity and the propagation is the same as in the straight tube where the current and pressure are in phase. This does not mean that the radiation in the two cases is equal, but merely that the wave propagation is the same as that in plane waves. We may observe, also, that at low frequencies, where $k^2\,r^2$ can be neglected compared with unity, the pressure and current become more separated in phase which reaches quadrature at zero frequency. Later we shall see that the exponential horn does not perform at these low frequencies as well as the straight conical horn.

The radiation along an infinitely long conical horn is given by equation (6). It is proportional to the square of the frequency and inversely proportional to the solid angle, ω. On comparing equations (3) and (6), the ratio of radiation along a tube to that along a straight cone for equal sound sources is thus equal to $\frac{\omega}{k^2\,\sigma}$. That is:

$$\frac{\text{Radiation along infinite tube}}{\text{Radiation along infinite cone}} = \frac{\omega}{k^2\,\sigma} \tag{8}$$

(See Rayleigh, "Theory of Sound," page 159, eq. 7.)

This ratio is equal to unity for a given tube and cone at some particular frequency, when the radiation in the two cases will be equal. For frequencies below this "critical" frequency the radiation along the tube will be the greater; while for frequencies above it, the radiation along the cone will be greater. To illustrate this, suppose $\omega = 0.01$ radian and $\sigma = 1$ sq. cm. Then when $k^2 = 0.01$, or the frequency is about 550 cycles, the straight pipe and cone give equal radiation. The cone is superior above 550 cycles and inferior below this frequency.

We have developed equations for the performance of exponential horns independently of Dr. Slepian and Mr. Hanna, using as the basis for this work the general equations given by Professor A. G. Webster in the *Proceedings* of the National Academy of Sciences, pages 275-282, 1919. Webster derived the same equation for pressure as given by Messrs. Hanna and Slepian in equation (51). Professor Webster also derived a similar equation for the current or velocity. Inasmuch as the authors have made no reference to Webster's publications, I presume they made no use of them. I think that Professor Karapetoff's remarks are appropriate and I am in accord with them.

Webster's equations apply to horns of any profile. He applied them to the following special cases:

(1) Straight pipe (σ = constant)
(2) Straight cone ($\sigma = \sigma_0\,X^2$)
(3) Exponential horn ($\sigma = \sigma_0\,\epsilon^{mx}$)
(4) For the case where $\sigma = \sigma_0\,X^n$ (hyperbolic when $n = -2$)
(5) For the case where $\sigma = \sigma_0\,\epsilon^{mx^2}$

Cases (1) and (2) were treated by him in some detail. The general equations for the pressure and velocity for the exponential horn were given. Case (4) was dealt with and the general equations given. In case (5), however, the method of analysis only was indicated.

If we separate Webster's exponential equations into the direct and reflected waves and put in the time factor, we obtain for the direct wave in the case of a horn of infinite length

$$\rho \frac{d\,\phi}{d\,t} = -\frac{\epsilon^{-\frac{mx}{2}}\,\rho\,A\,g\,a}{2\,\sigma_0\,k} \left[\cos(k\,a\,t - g\,x) - \frac{m}{2\,g}\sin(k\,a\,t - g\,x)\right] \tag{9}$$

$$2\,\sigma_0\,\epsilon^{\frac{mx}{2}} \frac{d\,\phi}{d\,x} = A\cos(k\,a\,t - g\,x) \tag{10}$$

$$P = \frac{\rho\,A^2\,\epsilon^{\frac{-mx}{2}}\,a\sqrt{k^2 - \frac{m^2}{4}}}{2\,\sigma_0\,k} \tag{11}$$

where $g = \frac{1}{2}\sqrt{4\,k^2 - m^2}$ and $\sigma = \sigma_0\,\epsilon^{mx}$.

The first two equations for the pressure and current correspond to equations (78) and (79) of Slepian and Hanna. The current equation (10) was written in the form given so that a comparison could readily be made between the cone and exponential horn for the same current or air velocity. The exponential horn is considered closed at the small end.

A comparison of equations (9) and (10) shows a leading phase angle between the pressure and current such that:

$$\cos\theta = \sqrt{1 - \frac{m^2}{4\,k^2}} = \sqrt{1 - \frac{m^2\,a^2}{4\,n^2}} \tag{12}$$

This result is identical to that given by Dr. Slepian and Mr. Hanna in their equation (82) n being equivalent to their ω. Our theoretical deductions, therefore, are in agreement for horns of infinite length.

I desire, however, to emphasize some of the deductions that may be drawn from these results. When $\sqrt{1 - \frac{m^2}{4\,k^2}}$ is zero the pressure and current are 90 deg. out of phase and no radiation results. This occurs when $m^2 = 4\,k^2$, or at a frequency, whose wave length is, $\lambda = \frac{4\,\pi}{m}$. If we take $m = 0.07$, then

$\lambda = 180$ cm., which corresponds to a frequency of about 185 cycles. m can be made smaller than 0.07 and in this case the frequency at which this occurs would be correspondingly lower. However, too small an m necessitates either too long a horn or too small a final opening in the case of horns of finite lengths.

In the case of the conical horn, however, we saw that it had a finite phase angle all the way down in frequency. At these lower frequencies, then, the conical horn should be superior on the basis of this simple theory.

If we refer to equation (11), the sound radiation at the initial end of the exponential horn is

$$P_{x=0} = \frac{\rho A^2 a \sqrt{k^2 - \frac{m^2}{4}}}{2 \sigma_0 k} \tag{13}$$

At frequencies sufficiently high to make $m^2/4$ negligible compared with k^2, equation (13) becomes

$$\underset{\text{(High Freq.)}}{P_{x=0}} = \frac{\rho A^2 a}{2 \sigma_0} \tag{14}$$

This result is identical with the straight pipe as shown by equation (3), provided the initial opening, σ_0, is the same as the cross sectional area of the pipe. That is, if $\sigma_0 = \sigma$ (of equation 3) the pipe and the exponential horn are identical in phase relations of current and pressure, as well as in the magnitude of the radiation from the source of sound into them.

To make a comparison under these conditions between the exponential and conical horns, suppose $\sigma_0 = 1$ sq. cm. and $\omega = 0.01$ radian. Under these conditions the exponential horn is inferior to the conical horn at all frequencies above 550 cycles as can be calculated from the relation:

$$\frac{P_c}{P_E} = \frac{k^2 \sigma_0}{\omega} \tag{15}$$

If, therefore, m is 0.07. $\sigma_0 = 1$ and $\omega = 0.01$ and the source of sound used gives the same velocity when used on both horns, the conical would be superior below 185 cycles and above 550 cycles, while the exponential is superior between these two frequencies. Incidently, curves which we have taken of sound pressure and frequency on horns of finite lengths indicate that this result holds approximately even when the source is placed at a finite distance from the vertex of the cone.

It is important, therefore, to observe that in the three cases considered the cross sectional area of the pipe, the solid angle of the cone and the initial area of the exponential horn all enter the power equations in the same manner and have nothing whatever to do with the phase between the pressure and velocity. This is important to observe in any comparative tests that may be made. For this reason it seems to me, if for no other, the demonstration with the various horns made by the authors are not conclusive and are apt to be misleading for by changing slightly the conditions the comparative results are altered greatly.

These results, of course, do not detract from the excellent results which the authors have presented—they merely emphasize certain features and indicate what we owe to Professor Webster for his splendid work in the field of acoustics.

Since these conclusions are of practical value, it is of importance to test them experimentally. Two horns of heavy galvanized iron were made—one being exponential and the other conical. Their lengths were 122 cm., had an initial opening of 1.6 cm. and a final opening of 31 cm. for the conical horn and 38 cm. for the exponential one. As far as radiation is concerned the larger final opening of the exponential horn gives to it a slight advantage. m corresponds to 0.052 and therefore the "cut-off" frequency, so to speak, was about 135 cycles.

Curves of sound pressure at various frequencies taken for these two horns indicate clearly the correctness of our conclusions. There was no question about the result that at those frequencies below 200 cycles the conical horn was much superior in accordance with our theory. These results suggest that the author's conclusions in section IV are probably only partly correct. These experimental results also suggest that if a receiver unit is placed at the small end of a conical horn, the latter perhaps radiates as though the unit were placed at the vertex and not as though it were placed at a finite initial opening. That is, it seems to me, that equations **100** to **104** given by the authors perhaps do not hold experimentally and are perhaps of theoretical value only since the basis of their derivation may be found to be incorrect experimentally.

As stated in the beginning of my discussion, the above results are of theoretical interest only because they deal with horns of infinite length in which no end reflection occurs and hence no resonant phenomena come into play. As already stated, Dr. Goldsmith and I will present in a forthcoming publication[1] experimental and theoretical results on horns of finite lengths, covering certain phases of our work in which the questions of acoustic impedances, resonance, effect of horn on external pressures, energy radiation, end reflection, etc., will be considered in some detail.

Merely to illustrate the type of results obtained, I give below two equations. One shows the effect of the conical horn on the external pressure, p_e, and the other shows the effect of the exponential horn. The ear, of course, is a pressure device and for this reason we are more interested in pressures than in other factors. The first equation was derived by Professor G. W. Stewart and published in the *Physical Review*, pages 313-326, 1920. The second equation, derived by us, is similar to Professor Stewart's, except it applies to the exponential horn. p_1 is the pressure at the small end of the horn.

$$p_1 = \frac{p_e}{\frac{\sin k r}{k r} + \frac{\sigma_2 \sin k (r - \epsilon)}{r \sin k \epsilon} \left(\frac{k}{2 \pi} i - \frac{1}{c_0} \right)} \tag{15}$$

(Stewart) conical horn.

$$p_1 = \frac{\sqrt{\frac{\sigma_2}{\sigma_1}}\, p_8}{\cos g L + \frac{m}{2 g} \sin g L + \frac{\sigma_2 k Z_0}{g \beta} \sin g L} \tag{16}$$

(Minton-Goldsmith) exponential horn.

Symbols which have not already been defined are as follows: r = radial length of the cone, L = axial length of the exponential horn, c_0 = acoustic conductance of the large end of the horn, $i = \sqrt{-1}$, ϵ is defined by $\tan k t = k r$ and σ_2 is the cross sectional area of the large end of the horn. Z_0 is the acoustic impedance of the large end treated as a fictitious cylinder of definite length and an opening equal to the diameter of the large end. The equation for Z_0 is $p\, a^2 k^2 \left(\frac{k i}{2 \pi} - \frac{1}{c_0} \right)$ (see our paper referred to, Appendix II, eq. **19**, p. 473) and is similar to the same factor in equation (15) above. $\beta = \rho_a k^2$, whose factors have been defined $g = \sqrt{k^2 - \frac{m^2}{4}}$.

By means of these two equations we are able to study pressure changes caused by both the finite exponential and conical horns. The effect of resonance, therefore, on external pressures is easily observed. Since experimental data on pressure are available we are able to check the theory. Similar equations have been obtained for the other factors enumerated above, but need not be given here. We believe, therefore, that an

1. "Performance and Theory of Loud Speaker Horns," Proceedings Institute Radio Engineers, August, 1924.

extension of Professor Webster's and Professor Stewart's work has led to results which are of prime importance in the study of horns of finite lengths and of various sizes and shapes.

J. Slepian (by letter): The simple experiments which Mr. Hanna has performed are not the only experimental verification of the theoretical results in the paper. Mr. Hanna has measured the increase in loading or acoustic damping produced by a horn, by impedance measurements of the receiver with an a-c. bridge, and has obtained very good checks with the theory. I have also some experimenting curves obtained by Prof. Dayton Miller of Cleveland, which bring out some points very clearly.

Prof. Miller used a specially constructed diaphragm and mirror, which could be attached to any of the various horns which was tested. On sounding a series of organ pipes before the horn, Prof. Miller observed the motion of the diaphragm by means of the mirror, and thus obtained a curve of diaphragm motion against frequency, such as those which I am about to show.

At first sight it would seem that these curves would not give the information desired as to the performance of horns on loud speakers, for what is wanted here is the sound which is produced at various frequencies for a given force on the diaphragm. However, a very interesing and general relation exists which enables us to change over from this data on the properties of a horn as a pickup of sound, or means for converting acoustic power into

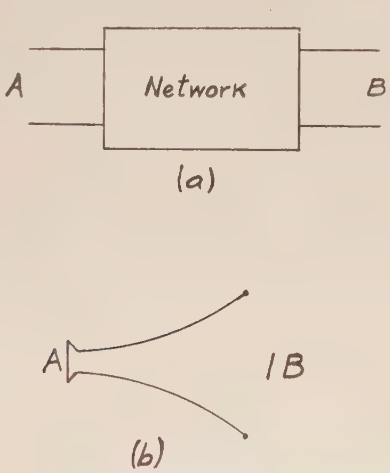

Fig. 1

diaphragm vibrations, to data on a horn as a radiator, or means for converting diaphragm vibrations into sound.

This being a gathering of electrical men, I shall give the electrical form for this relation, first; this is known as the reciprocal relation for electrical networks. Let A and B, Fig. 1A, be two pairs of terminals joined by a network built up out of simple impedances in any manner. Then if one ampere is made to flow into the terminals A, the same voltage will be produced at B as would be produced at A if one ampere is caused to flow at B. It is very interesting to check this relation for a few simple cases.

The acoustic analog of this relation is then as follows: In a given space containing bounding walls of any description, a source of sound of given intensity at a point A, Fig. 1B, will produce the same pressure on a diaphragm at a second point B, as would be produced on a diaphragm at A if the source of sound were moved to B. A more precise statement of this proposition may be found in Rayleigh's Theory of Sound, Vol. II, p. 131.

It follows then, that on sounding organ pipes of different frequencies, but with the same intensitybefore a horn, the curve of pressures developed on an attached diaphragm will be the same as the curve of acoustic loading which the horn would impose on the diaphragm if used as a loud speaker. For an exponential horn, we should then expect to reproduce the curve, Fig. 8, of Hanna and Slepian's paper.

However, Prof. Miller did not measure the pressure developed at the diaphragm, but the motion resulting from this pressure. We should therefore consider what motion would be produced in the diaphragm by a constant force of varying frequency. The motion of the diaphragm will be determined by its mass, stiffness and damping. The influence of the horn, when it is effective, will be to increase the damping. An important point brought out in Hanna and Slepian's paper is that the loading of a horn for

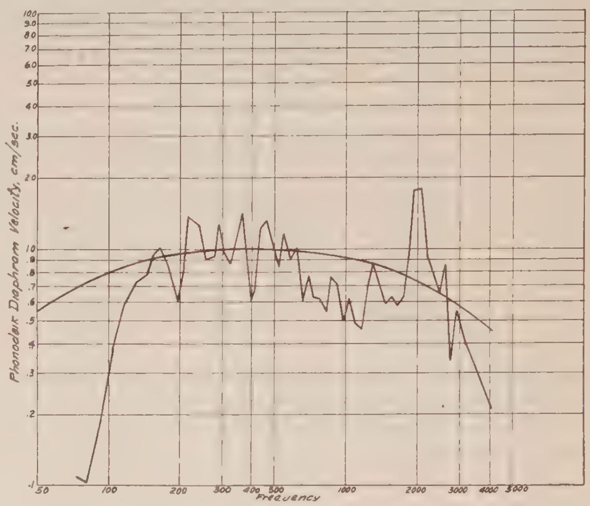

Fig. 2

the frequencis for which it is effective, is the same as that which would be produced by an infinite straight tube having the same section as the throat of the horn.

Mr. Hanna has calculated what the motion of the diaphragm would be under a constant force when loaded by an infinite straight tube of the same section as the throat of the horn. His results are shown by the smooth curves in Figs. 2 and 3.

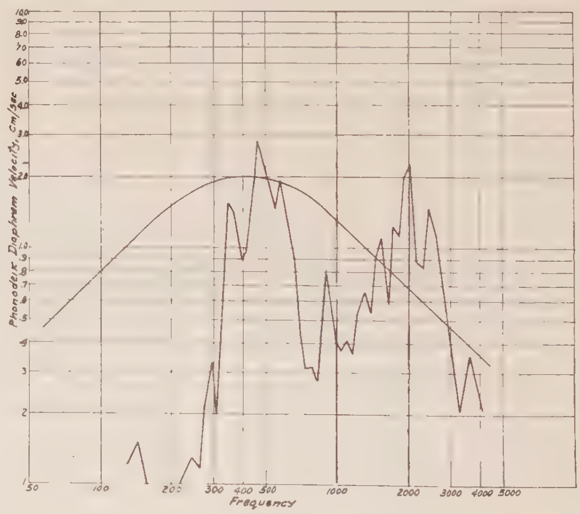

Fig. 3

Before discussing these curves, I would like to call attention for comparison to Fig. 10 of Martin and Fletcher's paper. Curve A of that figure is said to be the output curve of one of the best commercial types of loud speakers. The response begins to fall off at about 800 cycles and is one tenth of its maximum at 600 cycles. Now the falling off in response of this type of loud speaker at low frequencies is entirely due to the failure of its horn to sufficiently load the diaphragm, for the electromagnetic force for a given current is just as great or greater at low frequencies as for high. That is, when the acoustic loading of the horn

is too small, such large amplitudes of vibration of the diaphragm are necessay to produce appreciable sound, that most of the magnetic force is used in overcoming the stiffness of the diaphragm, and little is left for doing work on the air. We should expect then, that if a better horn were used, one which would load down to lower frequencies, a much better response curve would be obtained.

The curves obtained by Prof. Miller bear this out. Fig. 2 is for a horn whose throat area was 0.81 cm^2. and whose section increased at the rate of 4.5 per cent per cm. of length. We see that it gives the full loading corresponding to an infinite straight tube of the same section down to about 150 cycles, and we must go down to about 100 cycles before its loading effect is reduced to one tenth. This is not only very much better than the curve for the commercial type of loud speaker shown by Messrs. Martin and Fletcher, but even compares well with their laboratory models.

Fig. 3 is for an exponential horn having three times the throat area, and two times the rate of increase of section as the horn of Fig. 2. According to the theory, the loading of this horn with larger throat should be only one third that of the other horn, and so the resonances of the diaphragm should be more marked. This is seen to actually be the case. Besides the fundamental diaphragm resonance, which is the only one which Mr. Hanna considered in calculating his smooth curve, there is also a higher order resonance at about 2000 cycles. Since the rate of increase of section of this horn was about twice that of the preceding horn, the experimental curve should depart from the smooth curve at about twice the frequency for the first horn, and again this is seen to be the case.

The question has been raised as to whether the use of a horn is essential to a loud speaker, or whether sufficiently good results may not be obtained by acting on the air with a sufficiently large diaphragm. The principal objection to a horn is that if it is to be good, it must be quite long. However, the length which a horn must have is determined very largely by the amount of acoustic loading which it must impose upon the diaphragm. A uniform response will be obtained if this acoustic damping force on the diaphragm is about as large or larger than the force required to accelerate the diaphragm because of its mass, or the force required to displace the diaphragm due to its stiffness. Now, with materials capable of being used at present, it is not possible to get acoustic loading large compared to the inertia reaction of the diaphragm if the diaphragm acts directly upon the air.

Thus, suppose a large diaphragm is used, made of material whose density is 2, and whose thickness is 0.01 cm. The mass per cm^2. is then 0.020 grams. Suppose this diaphragm is vibrated at 3000 cycles, generating sound waves. The reaction of the air which gives a damping force on the diaphragm, has for one component, the force necessary to accelerate about one quarter wavelength of air, for this amount of air may be said to move with the diaphragm. Now at 3000 cycles, one quarter of a wave-length is only about two and one-half centimeters long, and the mass of a column of this length and one square centimeter in section is only 0.003 grams, which is only 15 per cent of the mass of a square centimeter of the diaphragm. Of the total force on the diaphragm, only 15 per cent is doing useful work on the air, and the rest is consumed in merely moving the mass of the diaphragm to and fro. It is true that this wattless component of force may be counterbalanced by a wattless component of force arising from the stiffness of the diaphragm, but for a finite diaphragm, having no mechanical loss, this compensation can be effective only at certain particular resonant frequencies. Between each successive pair of resonant frequencies, there will be an anti-resonant frequency at which the ratio of force actually acting on the air to total force on the diaphragm will be very much less than the 15 per cent above.

If, for the sake of discussion, we consider an infinite diaphragm, then the resonances disappear, but most of the force on diaphramg is spent in producing waves in the diaphragm itself, which radiate away from the region of application of the force. These waves will be only slightly attenuated by the air. Hence, returning to the finite diaphragm, if there is to be no reflection of these waves at the periphery of the diaphragm and resulting resonances, these waves must be caused to be more strongly attenuated by internal losses in the diaphragm itself, or reflection prevented by losses at the periphery.

In any case, we may conclude, that with a diaphragm of the mass considered, at least seven times as much force must be expended on the diaphragm as actually takes hold of the air, and in practical cases, allowing for losses and anti-resonances, it will be 20 to 100 times as much.

Any electrical engineer will recognize that what is needed is some kind of a coupling or transformer which will compensate for the great disparity in masses of the air and diaphragm. The corresponding electrical problem, would be to effectively load a source of alternating voltage having a high internal reactance when only a resistance of relatively small value is available. The obvious solution of this electrical problem is to interpose a transformer which will cause a large current to flow through the resistor with only a small current through the source of voltage. The effective resistance of the load referred to the primary side of the transformer is to the actual resistance in the secondary as the square of the ratio of turns, so that the resistance is thus stepped up to a value where it is comparable with the internal reactance of the source of voltage.

Now the chamber and throat of a loud speaker constitute just the kind of transformer desired. A small velocity of the diaphragm causes the air in the throat to have a large velocity. In the horns described by Messrs. Hanna and Slepian, the ratio of these velocities is 25 or more. The effective mass of the air is thus stepped up several hundred fold to where it is comparable with the mass of even the ordinary iron diaphragm. When loaded by such a horn, 50 per cent or more of the total force on the diaphragm is actually spent on the acoustic load, over most of the acoustic range. The mechanical power factor is thus high, and mechanical resonances greatly reduced.

Without a horn, then, for diaphragm materials so far available, the mechanical power factor is very low except at certain resonant frequencies. A very large mechanical input is necessary for a given volume of sound. To reduce the troublesome distorting effect of mechanical resonances, mechanical losses or electrical losses, electrical filter circuits will be necessary. These, however, will not reduce the mechanical input necessary, but rather increase it. A relatively large electrical power plant is then necessary.

Will a large hornless diaphragm save space, then? Possibly, since the large amount of extra electrical apparatus necessary, may be made very compact, and may perhaps be put in a somewhat smaller volume than required for a horn. But the saving will be small, and in my opinion, will not be worth while because of the extra complication and expense. Future improvements in the use of light weight diaphragm materials may reduce the amount of electrical apparatus necessary, but a diaphragm of such material would also permit a shorter horn to load it properly. The normal course of development, it seems to me, as we learn how to use lighter diaphragms, would be to use loud speakers with large diaphragms and shorter horns, but the possibility of arriving at a diaphragm so light that it is best used directly on the air, without a horn, is quite remote.

CERTAIN FACTORS AFFECTING TELEGRAPH SPEED[1]

(Nyquist)

Philadelphia, Pa. February 7, 1924

Bela Gati (by letter): The following remarks apply to cable telegraphy. Some experiments with a-c. telegraphy have

[1] A. I. E. E. Journal, Vol. XLIII, February, p. 124.

been made by the writer which are of interest in considering telegraph speed. These tests were made on long lines and oscillograph records of two of the tests which are shown herewith. In one case direct current was employed and in the other alternating current at 500 cycles per second.

In each oscillograph the lower line represents the current at the sending point while the upper line represents the received current. The point b shows when the current was started at the sending end. Point c shows when it started at the receiving end. Point d shows when the current was interrupted at the sending end.

From the oscillograms we see that in the case of the alternating current the received current stops sharply at point e, but with the direct current, the conductor discharges afterwards at its

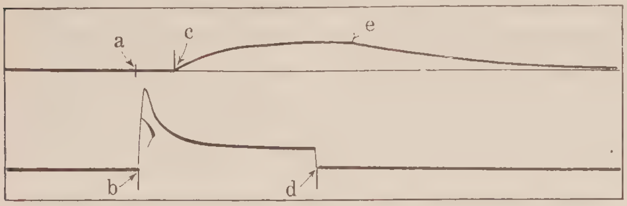

FIG. 1

natural frequency. The signal is lengthened from the point e to infinity.

This discharge current is the troublesome feature but there are several ways of lessening the time of discharge. If a cable is not charged to too high a value, especially at the end of the signal, the discharge current will be lessened. The grounding of the circuit at the sending end relieves the sending end of the long discharge and thus makes telegraphy faster.

It is still better to apply an opposing potential. This reduces the strength of the signal but it decreases the charging current. This is the method of Pickard and others.

The best method is to use alternating current. In this case each half cycle counteracts the effect of the previous half cycle. True, the strength of the current is appreciably diminished but the discharge effect is practically eliminated. The first and the

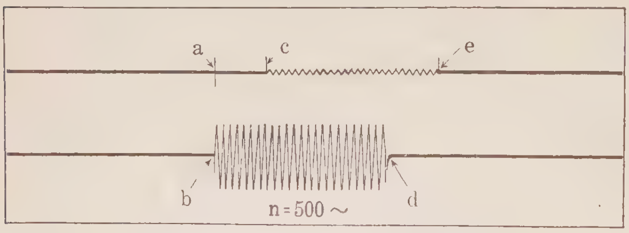

FIG. 2

last half cycles do not have any noticeable effect on the length of the signal.

The received current corresponding to a dot can be obtained from the superposition of two curves, each representing the received current for direct current. One of these curves is displaced along the time coordinate by an amount equal to the duration of the dot and it is plotted with negative values for the ordinate. The result is similar to the ripples obtained with alternating current, if the dot length is made equal to a half cycle. Of course, there are secondary and tertiary phenomena which modify the results and consequently there will be some disagreement between the two curves.

In my opinion the signal should contain ten complete cycles for a dot. This means that telephone frequencies (500 to 2000 cycles per second) are applicable.

The constants used in the experiments from which the oscillograms were taken were as follows: The circuit was 2120 kilometers of bronze wire, 4 millimeters in diameter. For each kilometer: $r = 2.8$ ohm; $l = 1.43 \times 10^{-3}$ henry; $c = 12 \times 10^{-9}$ farad; $g = 10^{-6}$ mho; $Zo (=$ Sending-end impedance as proposed by Dr. Kennelly$) = 348.46$ (at $-$ 5 deg. 17.85 min.); the attenuation $= 41.82 \times 10^{-3}$ (at 84 deg. 13.09 min.) $= (42.13 + j\,416.07) \times 10^{-4}$; attenuation $\times$ length $= 8.8$; the so-called "cable length" of Dr. K. W. Wagner $= \frac{t}{2} \sqrt{\frac{c}{1}} \times 2120 = 8.57$.

Of course this line is not a cable but it serves to illustrate the phenomena. On a submarine cable the point e cannot be exactly distinguished. The conditions are quite complicated and a simple explanation does not apply exactly.

Shunt coils in a cable compensate for the discharge effect and make alternating-current telegraphy possible for a given frequency. There is no reason for the limiting of the frequency to four cycles or ten cycles as is done in the computations of the extremely conservative cable companies. We must apply telephone frequencies giving many cycles for one dot. Only when using such frequencies can the benefits of shunt coils be realizied The use of shunt coils as applied now at the sending and receivng. stations is an entirely different matter from their use with telephone frequency and mounted at proper intervals on the cable. The shunt coils lengthen only the wave length but not the signals. Pupin coils shorten the wave length.

In 1909[2] I first proposed submarine cables with rather high self-induction, 10^{-2} henry. After 15 years, in 1924, the Western Union Cable Company has adopted a cable with such a characteristic.

If but one frequency is considered automatic multiplex printers may be employed (the Murray, for instance) and by this means the cable companies can compete effectively with the new 35-70-cycle channels of the new radio system.

For further information on this subject see the following articles by the present writer: Will the Signal be Lengthened in Alternating Current Telegraphy? The *Electrician*, London, April 12, 1912; Werdin die Zeichen auch bie Wechselstromtelegraphie verlaengert? *Elektrotechnik und Maschinenbau*, Wien 1911, Heft, 42.

H. Nyquist: As I understand it, there is very little disagreement between Mr. Gati's results and those obtained in the paper. The principal discrepancy occurs in connection with the matter of improving submarine cable signals by grounding the transmitting end of the cable for short intervals. In the paper the opinion is expressed tentatively that such grounding is not beneficial, whereas Mr. Gati comes to the opposite conclusion. It is to be regretted that his experimental work does not cover this point.

The argument that carrier telegraph at voice frequencies is preferable to direct current for signaling purposes is not, of course, applicable to the subject under consideration, namely, ocean cables as at present constituted. Such cables are incapable of transmitting these frequencies. In the case of the circuits which are capable of transmitting these high frequencies, it is, of course, possible to utilize them for telegraph purposes. In fact, in the case which Mr. Gati considers, namely, where the circuit is assumed to be capable of transmitting 10 cycles of alternating current to form a single dot, it is possible to go even further and to obtain both d-c. telegraph and carrier telegraph simultaneously.

There can further be no question that the introduction of suitable loading extends the frequency range and, therefore, is beneficial, if properly applied. I am under the impression that the reason telegraph companies have not employed loading for submarine cables up to the present is not lack of appreciation of the effectiveness of such loading but rather the lack of suitable methods for accomplishing it.

[2]The C R Law and Rapid Cable Telegraph, *Elektrotechnik und Maschinenbau*, Issue 37, 1909.

MEASURING METHODS FOR MAINTAINING THE TRANSMISSION EFFICIENCY OF TELEPHONE CIRCUITS[1] (Best)

Philadelphia, Pa., February 8, 1924

W. H. Harden: Mr. Best's paper in dealing with the development of telephone-transmission testing apparatus describes three of the common forms of instruments and mentioned the oscillators employed to supply the testing current. It may be of interest to outline briefly some of the more important applications which are being made of these testing devices in maintaining the efficiency of telephone circuits in the Bell System.

The three types of instruments considered are the *1-A* and *3-A* transmission-measuring sets which are portable and the *4-A* transmission-measuring set which is designed for permanent installation. The *1-A* type of set has been used extensively during the past eight or nine years and prior to the advent of instruments employing vacuum tubes a majority of the important exchange area circuits in the System were tested with this set. There are at present approximately 150 sets of this type in the Bell System.

When the *3-A* type of set came into use two or three years ago it replaced the *1-A* type for certain classes of work but not all classes. The *3-A* set employing vacuum tubes and visual means of indicating transmission losses allows transmission tests to be made more quickly and accurately than the older type of set. It finds its principal application in testing the larger units of plant, such as common-battery central offices, both manual and machine switching. It is also used to some extent in testing toll circuits. For the smaller units of plant, such as private-branch exchange switchboards, magneto switchboards, etc., where the power necessary for operating the *3-A* set and its oscillator is not available locally, the *1-A* type of set is still generally used. There are at present approximately 100 sets of the *3-A* type in the Bell System.

The testing work using these two types of sets is usually carried on by teams of two men each who travel from office to office. For average conditions involving both large and small central office areas one team can test from 30,000 to 40,000 circuits a year clearing all troubles which are found.

The *4-A* transmission-measuring set, or permanent type, is used extensively in maintaining the transmission efficiency of toll circuits. There are at present some 40 or 50 of these instruments installed at important toll centers about the country. Tests are made straight-away or looped between these centers at frequent intervals and also on the loop basis to the smaller outlying toll centers. The transmission efficiency of toll circuits of all types, such as, 2-wire, 4-wire or carrier, can be quickly checked with the arrangement as outlined.

One thousand-cycle measuring current is now used for all routine tests on toll circuits and on all tests of exchange area circuits where the *3-A* type of set is employed. The 800-cycle oscillators which are now in the field are still being used for exchange-area testing with the *1-A* type of set and are satisfactory for this work. Whenever it is necesary to check the transmission-frequency characteristics of any circuits the *4-A* type of set is used in conjunction with the *4-A* type of oscillator which can be made to give any desired frequency within the voice range.

This line of transmission-testing apparatus has enabled troubles which cannot be detected by ordinary tests, to be quickly located and cleared. Short-circuited turns in transformers, retardation coils and relays, incorrect wiring of certain equipment and certain defective equipment are examples of the kinds of trouble which require transmission tests for detection. The application of this testing apparatus has gone beyond the experimental stage and routine transmission tests are now an important factor in the maintenance of the telephone plant.

1. A. I. E. E. Journal; Vol. XLIII, February, p. 136.

H. H. Nance: At the beginning of the war period there had come into general use vacuum-tube telephone repeaters and toll cables carrying many circuits of different gages and types of loading. The range of telephone transmission was rapidly increasing, and longer and more complicated circuits were being established. Also, at that time the heavy demands for additional circuits, many of which were for the Government's use, necessitated the hurried installation of additional facilities, heavy growth in many instances being to outlying points where comparatively little traffic previously existed. Ofttimes it was a matter of putting together such facilities as could be obtained. All of these factors combined to present a serious problem from the standpoint of transmission maintenance and a heavy burden was placed on the forces maintaining the several thousand circuits then in operation in the plant of the long-lines department of the American Telephone and Telegraph Co. The situation was further complicated, of course, by the fact that skilled personnel required for this work was at a premium.

The development of the *3-A* and *4-A* types of measuring sets brought about a decided improvement in transmission-testing methods. From a practical standpoint the use of a single-frequency measuring current and direct meter readings were of particular benefit and greatly relieved the work of the trained observer. These methods eliminated to a large degree the personal equation, and more accurate and quicker results were obtained and at a very considerable saving in circuit time and testing labor.

The first sets of the *4-A* type were installed at New York and Washington, as these were two long-distance telephone centers of great activity at that time. By means of these sets, the two offices together could measure approximately 200 circuits in a night period of about seven hours, including the directing of repeater adjustments at intermediate points and clearance of trouble found, whereas by the older methods, which had consisted mainly of talking tests using artificial cable, this would have required many nights' work and a testing force several times as large, even if it had been practicable under the conditions to follow the older methods.

Since then, additional measuring sets of the *4-A* type have been installed at a considerable number of points well distributed throughout the long-lines plant and the methods and routine have been systematized to a point where the large number of circuits in this plant is now measured periodically.

A great many circuits, of course, terminate at points where these sets are not installed but measurements on such circuits can be obtained by connecting them through to a testing point by means of other circuits of known equivalents. In some cases the *3-A* or portable type sets, which are likewise well distributed throughout the plant, are used for measuring circuits which cannot conveninetly be measured from the nearest station at which a *4-A* type is installed.

The results obtained in accordance with the present methods and routine have been highly satisfactory, and it has been practicable to maintain the circuits within relatively close limits of variation from the computed equivalents.

The particular work mentioned, that is, the measuring of circuit equivalents from one terminal to the other is, of course, only a part of the transmission maintenance work, since a great many other measurements in connection with that work are made on individual repeaters, networks and sections of circuits at intermediate stations.

R. L. Simpson: The New York Telephone Company is making considerable use of the transmission measuring apparatus which is described in Mr. Best's Paper. In each of our seven Plant Divisions we have one or more specially trained forces whose function it is to maintain our circuits up to the proper grade of transmission efficiency. They conduct tests on all of our central-office and private-branch-exchange circuits and equipment.

In general, these forces are equipped with *1-A* and *3-A* transmission measuring sets; and, in addition, we have one of our divisions equipped with a set of the *4-A* type for the maintenance of toll lines which are equipped with through-line repeaters. Periodic transmission measurements are made on a 1000-cycle basis. The *1-A* set is used on small magneto switchboards and P. B. X. switchboards where 24-volt battery supply is not readily available. In our larger central offices where a considerable amount of apparatus is concentrated at one point, and battery supply sufficient to operate the *3-A* set is available, we use this instrument. The *3-A* set, being a visual reading type eliminates to a great extent the personal equation and by eliminating the necessity for personal judgment makes the test quicker.

Before the development of the transmission measuring sets, as described in Mr. Best's Paper, a transmission investigation on one of the larger offices in the Metropolitan division of our Company would require an expenditure of both time and money which would probably be out of proportion with the results obtained, but the facility with which circuits can be measured with both the *1-A* and the *3-A* set, makes it possible to accomplish this work both economically and quickly even though the investigation of one of our larger offices would mean the testing of something in the order of 5000 individual circuits, such as cord circuits, operators' telephone circuits, trunks, etc.

These instruments are so designed that they not only indicate the amount of excess loss present when trouble is encountered as compared to the known transmission standard of the particular circuit under investigation, but also make it possible in a large majority of cases to definitely locate the trouble and eliminate it while the circuit is under observation by the transmission tester.

Many of the troubles eliminated by this means are not obvious, nor is their location possible by the usual maintenance methods which are followed by the central office forces. It sometimes happens in the course of the installation of a large number of core circuits involving repeating coils and relays that, due to the amount and complexity of the work required in the installation, some of these coils are installed with one winding reversed. The effect of this would not be apparent on any of the routine tests which are made as these are all on a d-c. basis, but since the repeating coil acting as it does as a transformer with one winding reversed is very inefficient, the effect on the transmission efficiency of the circuit would be detrimental. A transmission measurement of the circuit, together with an investigation, will readily clear up this trouble.

The results of the tests which have been carried out in the New York Telephone Company have been invaluable to us not only due to the fact that we have been able to eliminate some rather obscure troubles, but also due to the fact that we can in many cases anticipate and prevent the reoccurrence of conditions which transmission measurements have shown to react unfavorably on the performance our circuits are designed to give, through analysis of the reports.

Bela Gati: I always had the opinion that the resulting transmission savings and improvements in service are worth many times the cost of doing the work.

The European government telephone practise has not followed the excellent example of the American Telegraph and Telephone Company as yet, consequently, it is believed to be a great success to speak over the territory of three States in Europe. Government employees are cheap in Europe (about $25 monthly salary for telephone engineers, in Hungary) thus the talking tests are not so expensive.

I agree with Mr. F. H. Best regarding the talking tests. I am glad that the American Telegraph and Telephone Company does not favor it any more, although the company was a great defender of this system and it is the sin of this company (Germans not excepted), that this American method has firm root in our poor Europe.

I wish to complete Mr. Best's objections in one direction. The talking tests do not count in the resonance question. Each 100 kilometers of line has different resonance effects for some speech frequencies, hence the incalculable results, obtained by suchinvestigations. In the TRANSACTIONS of the A. I. E. E., Vol., XXX, part II, pages 1679-1680, Multiplex Telephony and Telegraphy by means of Electric Waves Guided by Wires, George O. Squier, Discussion at Chicago, 1911 June 28, I pointed out clearly the resonance effect. If the outgoing current is not in phase with its voltage, then in that case we do not measure the attenuation, but we construct the resonance curve only. I believe this resonance effect disturbs also the results obtained by the various transmission measuring sets. In measuring long lines, the applied filter substitutes in some degree the necessary resonance state at the sending end.

The testing method of central office apparatus is an ingenious one. I quote but one example. Bucarest, the capital City of Roumania was unable to call Budapest, the capital City of Hungary directly, but always needed the intermediation of Brasso. This went on for years. The line signal coils and the clearing-out drop coils were changed by mechanics in Brasso's and this caused the inconvenience. I measured the fault from Budapest, which is a distance of 700 kilometers.

Our subscriber and city lines need measurements also. Paris could not reach Rome because of the interconnecting lines in Lyon. The French administration is not in favor of the secondary lines at all.

In the transmission measuring sets Mr. F. H. Best uses, according to the figures, ohmic resistances only. Kennelly's sending end impedance is needed at the end of the line and this always in the $a - j\,C$ form, $zo = \sqrt{\dfrac{r + j\,u\,l}{g + j\,u\,c}}$ compression means a resistance in series with leakance-free condensator. This condensator is missing, therefore the attenuation values differ from the actual ones.

In chapter *3-A*, Transmission Measuring Set, Mr. F. H. Best writes that "no alternating-current measuring instruments were available for measuring the power received at the end of a telephone circuit, which were sufficiently rugged or practicable to withstand the service required of them." I dont know whether there is an instrument which measures the phase displacement at the end of a long telephone line, but I measured the attenuation with my barretter apparatus 15 years ago. I modified Kennelly's barretter, using it in compensation bridge. I measured 100 microamperes telephone-current with Robt. W. Paul's pointer instruments. In loop, I used the same barretter for the outgoing and incoming currents; the d-c. microampere-meter readings were proportional with the square of the current. Keeping the outgoing current always at the same level (50 deg. deflections) from tables previously made the attenuation $\times$ length could be read at once.

I measured with these instruments at the bottom of the poles in moonlight, in rainy weather also. We had many auto-accidents, but Paul's microampermeter and the set remained intact.

F. H. Best: As it is not clear as to just what is meant by some of the points raised by Mr. Bela Gati, it may be that his comments can best be answered by referring to the general principle of the method used in the transmission measuring apparatus described in the paper. The measuring apparatus is designed to measure the transmission equivalent of a telephone circuit in such a way that the answer obtained represents the equivalent which this circuit would have were it connected in the center of a long line of its own type. For this reason the apparatus which is connected to the two ends of the circuit under test approximates in impedance the impedance of the circuit under test. For the most precise results this impedance should, of course, be exactly equal to that of the circuit under test. However, the com-

plexity of the testing apparatus necessary to permit an exact impedance match is not warranted. The values of the three impedance terminations included in the testing apparatus have been selected so that in testing any of the circuits in common use in this country some one of these terminations will meet the impedance of the circuit under test sufficiently closely to make the error introduced by the approximation so small as to be negligible. It has not been found necessary to have a reactance component in the impedance of the termination. Loaded circuits are so designed that the reactance component of the impedance at the end of the circuit is small. Non-loaded open-wire circuits have small reactance components. Even in the case of non-loaded cable circuits where the phase angle of the impedance may approach 45 deg. the error introduced by the use of non-reactive terminations is small.

As mentioned on page 4 of the article, the apparatus described is arranged to read the transmission loss or equivalent in terms of the loss in standard cable at a frequency of 800 cycles, the unit being commonly called the "800-Cycle Mile." This cable is the standard cable used for some time in this country, having a resistance of 88 ohms and a capacity of 0.054 μf. per mile with $G = 0$ and $L = 0$. This "800-cycle mile" of standard cable, which was a somewhat arbitrary unit, has recently been replaced in the Bell System by a "Transmission Unit," which is described in a paper by Mr. W. H. Martin, published in the June, 1923, Journal of the A. I. E. E. While of approximately the same size as the 800-cycle mile, this new unit is founded on a more logical basis, one unit causing a power attenuation of $10^{0.1}$. New testing apparatus will be calibrated in terms of this unit.

It is not evident what Mr. Bela Gati had in mind in the third paragraph of his comments in which he mentions "talking tests." Such tests have played an important part in development work and have been well justified, but because of the elaborate nature of such tests the American Telephone and Telegraph Company have never used or recommended the making of such tests as a routine method of determining the condition of operating circuits.

In connection with the Barretter mentioned by Mr. Bela Gati for measuring attenuation, it might be of interest to note that the current at the receiving end of a telephone circuit when it is being tested with apparatus described in this paper is in some cases as small as 2 microamperes. The output of the sending apparatus is one milliwatt. For received currents as small as 2 microamperes, it is, of course, necessary to use apparatus employing vacuum tubes. The current levels used in testing are selected to be of the same order of magnitude as the currents impressed on the lines and associated apparatus in telephoning.

Regarding the question as to the proper impedance of receivers, it should be noted that the most efficient receiver is one which matches the impedance of the circuit to which it is connected.

TELEPHONE TRANSFORMERS[1] (Casper)

Philadelphia, Pa., February 8, 1924

Wm. Fondiller: Mr. Casper has described the ideal transformer, one which would introduce zero loss in a telephone circuit, as represented by an equivalent network having zero impedance series arms and an infinite impedance shunt arm. In any practical transformer the factor which most largely determines the extent to which this ideal can be approached is the magnetic material used for the core. The ideal core material obviously would be one having infinite permeability and zero losses, as this would make possible 100 per cent coupling, practically zero winding resistance and infinite mutual impedance. Fortunately, however, a magnetic material having characteristics altogether finite in value will permit the construction of quite satisfactory transformers. It may be of interest to indicate what the desirable properties of the magnetic material should be and the extent to which they are attained in materials at present commercially available.

As Mr. Casper has indicated, the speech frequency magnetizing forces operating in these transformers are of low values, generally ranging from 0.001 to 0.05 c. g. s. units. These values are less than 1/100 of those ordinarily employed in power work. On account of the extremely low magnetizing forces, the part of the usual permeability characteristic which is of importance in material to be used in this apparatus is a small portion near the origin. Over this part of the curve the change in permeability with magnetizing force is not very large, consequently, what is commonly called the "initial" permeability may be used to define the relative merits of different materials. The requirements of a desirable magnetic material for the telephone transformer, so far as its action in transmitting speech frequency currents is concerned, are therefore, high initial permeability and low core losses at the corresponding flux densities.

The material which at present meets these requirements most satisfactorily is what is known as high silicon steel transformer sheet. This is a low carbon iron having from 3.5 to 5.0 per cent silicon and is supplied in sheets of 0.014 in. in thickness.

So far as I am aware, no steel mill is at present equipped to make the required tests at very low magnetizing forces. Due to this condition, the product supplied at present by the different manufacturers varies a good deal in respect to some of these magnetic characteristics. The initial permeability ranges from about 400 to 600. Frequently, however, values as low as 250 are observed. The maximum of these permeability values is, of course, desirable, although a steel consistently having an initial permeability of about 500 would be quite satisfactory. Eddy current loss is fairly uniform at about 1.0 erg per gram at a frequency of 1000 cycles per second and a maximum density of 15 gausses. The hysteresis loss under the same test conditions varies from about 1.0 to 5.0 ergs per gram in different samples. When the value of this loss is above 3.5 ergs the results are unsatisfactory. As brought out in the paper by Speed and Elmen, on "Compressed Powdered Iron" in 1921, the hysteresis loss is less in hard than in soft material for the same flux density at very low magnetizing forces. It will be evident from this that some conflict in requirements exists in that it is desired to secure high initial permeability in combination with low hysteresis loss. Until substantially lower hysteresis loss values can be obtained, there is little to be gained from reducing the values at present obtainable for eddy current loss at audio frequencies. The latter can, of course, always be reduced by employing thinner laminations.

The variations just cited make the problem of the design and manufacture of telephone transformers to consistently uniform standards of performance rather difficult. It is hoped that developments, which have been recently instituted in conjunction with some of the suppliers of magnetic materials, will in the comparatively near future make it possible to obtain such materials under suitable magnetic specifications. An important factor contributing to the attainment of this end would be the recognition of the performance requirements of magnetic materials for such uses as Mr. Casper's paper describes, in standardized tests such as those adopted by the American Society for Testing Materials. The present standardized tests for transformer sheets are applicable only to power frequencies and flux densities. What is needed to meet the requirements of communication engineering is a test for permeability and core loss at a flux density of about 15 gausses. This test could be made at a frequency of say, 1000 cycles with a bridge type of testing circuit using an ordinary telephone receiver as an unbalance detector. Simultaneous readings of inductance and effective resistance can be taken in this way from which the permeability and core losses are readily calculated.

I believe that the adoption of a uniform practise for specifying the characteristics of magnetic materials at low magnetizing

1. A. I. E. E. Journal, Vol. XLIII, March, p. 197.

forces would result not only in a more satisfactory condition as regards the production of telephone transformers, but would also lead to improvements in these characteristics due to a new appreciation by steel manufactures of the effect of their processes on the magnetic behavior of this material.

W. L. Casper: Mr. Fondiller has dealt with the use of silicon steel for the magnetic core material of the speech-frequency transformer giving figures for the initial permeability and the eddy-current and hysteresis losses. The much higher permeability and lower losses of permalloy as brought out in the paper by Arnold and Elmen before the Franklin Institute in 1923 naturally raises the question as to whether permalloy will not supersede silicon steel for this purpose. Obviously, wherever the circuit conditions are such as to require the transformer core to operate only at this initial value and not to require the introduction of gaps in the magnetic circuit these characteristics of permalloy will be of great advantage. For instance, the phantom-circuit repeating coil which is a toroidal-type transformer wound on a silicon-steel core and which weighs about 3½ lb., has been duplicated experimentally in efficiency to talking currents by a transformer of similar construction but having a permalloy core and weighing under two ounces.

As brought out in the paper, telephone circuits, as a rule, have to perform more functions than simply to transmit speech currents and the phantom-circuit repeating coil is required, in addition to this primary function, either to transmit 20-cycle signaling current or be inefficient to Morse telegraph currents. As the amount of energy transmitted under either of these two conditions is vastly larger than the speech-current energy in addition to the frequency being considerably lower, it becomes an involved problem in design as to whether permalloy would prove good, depending largely on the cost of the core material.

Another case where the complex circuit conditions prevent full advantage being taken of the large difference in initial permeability of permalloy over silicon steel is that of the transformers which operate with direct current through their windings as, for instance, the input transformer. The design of such a transformer involves proportioning the core in such a way as to give maximum permeability under the operating conditions which is done by the introduction of an air gap of suitable length. Obviously, the greatest gain by the use of permalloy will be made in input transformers operating from low-space-current tubes. Whereas the economic advantage of permalloy is marked in transformers operating from tubes employing one or two milliamperes space current, its superiority is reduced when this space current is 10 or 20 milliamperes, requiring the cost of permalloy to be not greatly above the cost of its constituents in order to prove satisfactory.

Permalloy is being used at present in a number of those transformers which operate under conditions where maximum advantage may be taken of its high initial permeability and economic studies are in progress to determine under just what other circuit conditions it will prove advantageous.

AN ELECTRICAL FREQUENCY ANALYZER

(Wegel and Moore)

Philadelphia, Pa., February 8, 1924

H. Fletcher: I desire to emphasize the tremendous difference in the time required for obtaining analyses by means of this machine and by the method which has usually been employed in the past. After the electrical connections are made, all you have to do is to press a button and then after waiting five minutes you have a photographic record of the analysis before you are ready for examination. This machine will do in two or three hours what previously required as much as two or three months' work for obtaining the spectrum analyses of such sounds as the output of a horn or organ pipe.

Since the development of the condenser transmitter, which has a practically uniform response with frequency, and of amplifiers, which have similar characteristics, it is now possible to use these new tools for picking up an acoustic wave and transforming it into electrical form without any appreciable distortion. When it is thus transformed it can be sent through the analyzer and in five minutes' time an analysis can be obtained which shows the frequency and magnitude of the components. You can readily see the tremendous advantage such a device will be in research work.

For example, we were trying to find the essential physical thing that caused one to judge the pitch of a musical tone. It is well-known that practically every musical tone has a large number of components, the fundamental and a series of harmonics. We were very much surprised to find that the elimination of the lower frequency range, including the fundamental and first few harmonics, did not change the pitch. For example, musical tones were observed, which had no component frequencies below 500 cycles per second, which still gave a pitch corresponding to a simple pure tone having a vibration frequency of 100 cycles per second. Naturally, when we first observed this phenomena, we were somewhat skeptical of the fact that these frequencies were actually eliminated. This harmonic analyzer soon gave us convincing proof that they were absent.

Another example will suffice to show the usefulness of this apparatus for acoustic work. In studying the acoustics of rooms, if one took a record of a sound wave under certain conditions, and then had to wait two or three weeks before obtaining an analysis of this wave before making any changes in the room, such as, moving some of the furniture, it is evident that the progress would be very slow. With this device one can get an acoustic picture of what is taking place in the room, move a desk, or something else which you are interested in, and then take another picture, etc., so that in a few days time you can accomplish what used to required months without such a device.

L. P. Ferris: This paper describes a device which may be very useful in making investigations of wave form of power machinery such as may be carried out by large manufacturers. Because of its weight and bulk, the instrument is not suitable for making investigations in the field but for permanent installation in a large test room or laboratory, this would not be a serious drawback. Investigations are now being made of wave shape of power machinery involving the higher harmonics which are difficult to measure with the oscillograph. It is hoped, in these investigations, to obtain information looking toward the reduction of these harmonics because of their contribution to telephone interference. A device built along these lines may be of great assistance in these investigations, by disclosing quickly the magnitudes of the harmonics.

MULTIPLE SYSTEM OF COOLING LARGE TURBO-GENERATORS[2] (Bratt) and AN EXPERIMENTAL STUDY OF VENTILATION OF TURBO-ALTERNATORS[3]

(Fechheimer)

Philadelphia, Pa., February 8, 1924

S. L. Henderson: The papers of Mr. Fechheimer and Mr. Bratt are of primary interest to the designer; particularly to those designers of large machines which require more than the usual air gap entrance for the admission of cooling air. To others, the papers will indicate the amount of research work which is being carried on to enable the manufacturer to build larger and better machines. To the designer the methods for calculating the air circuits may appear complicated and not easy of application. However, when the importance of the

1. A. I. E. E. Journal, Vol. XLIII, September, p. 798.

2. A. I. E. E. Journal, Vol. XLIII., March, p. 185.
3. A. I. E. E. Journal, Vol. XLIII., May, p. 416.

proper ventilation system is considered, the designer may well spend considerable time in laying out this part of his design. When it is realized that the construction cannot be changed once the machine is built and that the design of the machine must stand or fall on the ventilation system as laid out, too much time and care cannot be spent in its layout. In the application of the methods put forth in these papers, as in all designs, a first approximation must be made of the relative widths of the different intake and outlet belts and the pressure drops required in the different paths. When once this is done, the designer can readily see how the proportions need to be changed so that the pressures in the various paths will balance up and also so that the proper velocity distributions may be obtained.

The methods have been used in the design of a number of different machines, and Fig. 36 in Mr. Fechheimer's paper shows how the tests on one of these machines came out. The curves of velocity distribution are somewhat flatter than the calculated values; *i. e.*, the velocities in the radial ducts are more uniform than as calculated. In other words, the calculations are on the safe side.

Edgar Knowlton: A number of years ago the company with which I am associated had occasion to build a machine which was ventilated very much the same as described in Mr. Fechheimer's Type 1. We found this was unsatisfactory, and after several years' operation the machine was changed to a type of ventilation where the air entered both ends of the air gap and was discharged radially through the air ducts. This change was of considerable benefit.

When we first began the use of the system of ventilation whereby the air entered both ends of the air gap, it was very satisfactory for the quantities of air and velocities at which the air entered the gap. Later it was found necessary to chamfer the air gaps, and it was rather remarkable that in some cases the quantity of air was nearly proportional to the increase in the area of the entrance to the air gap.

I would like to ask if Mr. Fechheimer found difficulty in closing the air ducts, and if that were the reason why he used the "toy balloon" method? I consider this a very ingenious device.

I would also like to ask if any negative pressures were found in the air ducts alongside of the armature coils?

We have found some cases where zero pressure existed on salient-pole machines with low peripheral speeds, and in one case, recently I had occasion to examine a machine which was somewhat unusual, in that it had — ¾-in. pressure on one side and + 1.5 in. on the other side of the armature coil.

G. E. Luke: This problem of cooling large turbo-generators is getting to be a greater one each year. The aim of the designer is not only to produce a more reliable machine but also to design one with a maximum output per pound of material. The great advances made along this line account in part for the fact that the cost of power to the consumer has not increased and in many cases has decreased in spite of the fact that other costs have materially increased.

In the cooling of an electric machine, we are practically limited to the use of air as a medium for the carrying away of the losses. The reasons for the almost universal use of air are due to its unlimited supply, its mobility or the ease with which it can be forced to flow over the ventilating surfaces, and its high insulating qualities. Other mediums such as water and oil have been used, but only in a few special cases.

The cooling of a machine with air involves three important problems: first, the conduction of heat to the ventilating surfaces; second, the transfer of heat from these surfaces to the air; and third, the proper distribution of air over the cooling surfaces. There are many systems of ventilation used and these two papers cover a detailed investigation of two of these systems experimentally and analytically. They particularly deal with the means for determining the air distribution and for evaluating the relative importance of the various factors determining this air flow. You cannot emphasize too greatly the fact that a properly designed machine necessitates a correct distribution of the air over the ventilating surfaces.

The presence of what are called "hot spots" may be due to an improper air distribution. What is attempted by the designer is to ventilate best those parts of the machine which have the greatest loss. In other words, the air velocities over the surfaces should bear an almost direct proportion to the unit watts loss dissipated from these surfaces.

Thus in Fig. 1 with the radial system of ventilation, the highest air velocities are found in the zone of maximum loss, that is, the tooth zone. The amount of heat loss which can be liberated from a given surface for a given surface temperature rise is almost proportional to the average air velocity such as shown by the solid line curve, Fig. 2.

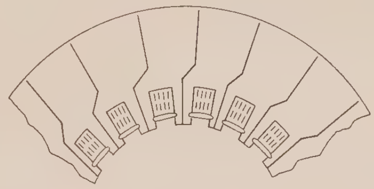

Fig. 1

But the limiting temperatures are the maximum copper temperatures found in the embedded copper. The copper loss must be conducted through the insulation (which is also a good heat insulator) to the iron. Here it is added to the iron loss and both losses are conducted through the iron to the ventilating surfaces. Both steps in this conduction of heat must be accompanied by a temperature difference which may be quite large, especially the gradient necessary to cause the copper losses to flow through the insulation. This temperature gradient from the "hot-spot" to the ventilating surface is always present and is proportional to the loss dissipated and cannot be decreased by an improvement in ventilation. If we plot watts loss in the machine for a given temperature rise of the copper, the curve, Fig. 2, changes from a straight line to a curve as shown in dotted line, due to this internal temperature gradient.

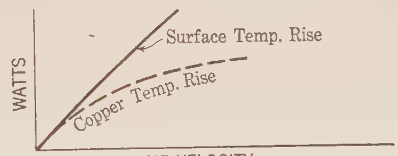

Fig. 2

The experimental tests made by the authors are especially difficult. They involve the measurements of very small air pressures and velocities in very limited and inaccessible positions. An analytical treatment of the air flow, such as Mr. Bratt has given us, is valuable in that it permits of the possibility of calculating the effects of the various factors. Many difficult points are found in the air flow problem. Thus in Fig. 1 the air must change in velocity very greatly as it is forced to flow through the tooth zone where it is obstructed by the windings, the slot wedges and the ventilating fingers. The authors have found that the pressure required to force a given quantity of air through such a passage depends upon the direction of air flow whether radially outward or inward.

R. B. Williamson: The problem of the ventilation of turbo-generators is a complicated one involving as it does, the handling of large volumes of air in a very restricted space. In order to cool a machine of given size, a certain minimum amount of air must be passed and this air must be distributed

so that all parts of the stator will be uniformly cooled, or at least the distribution must be such that the hottest parts will be well within the safe limits permissible for the class of insulation used. Furthermore, this volume of air must be circulated with moderate end-bell pressures such as can be readily developed by centrifugal fans mounted at each end of the rotor.

In general, two methods have been used for distributing the air; these may be termed the axial method and the radial method. In the axial method the air passes axially (parallel to the shaft) from each end bell through the air gap and through longitudinal flues or ducts in the punchings back of the teeth and discharges in the center part of the stator. While this method is satisfactory for relatively short machines, it gives rise to a hot region in the central part of long stators for the reason that the air as it passes longitudinally through the stator becomes heated as it progresses towards the centre, and the air for cooling the central part is hot by the time it reaches these parts. In the radial system, as its name implies, the ducts are radial or annular, the core being sub-divided by a relatively large number of ducts as indicated in Figs. 1 and 2 of the paper. The laminations are thus sub-divided into a number of sections of small axial width, usually not over 1½ to 2 inches as measured parallel to the shaft. The present paper describes tests of air flow in the different types of radial ventilation referred to as Method I and Method II, both of which provide a number of relatively short paths in parallel for the flow of air after it leaves the end bells. The sub-division of the flow into a number of parallel paths cuts down the distance that the air has to travel from the time it enters the machine until it leaves it, thus permitting the use of moderate air pressure. Again, if the paths are suitably arranged, and the vent spaces in the ducts properly designed, very even cooling can be obtained. As far as my personal experience is concerned, it has had to do almost entirely with Method I which has been used successfully for the past 14 years with machines ranging in size from 1500 kv-a. to 27,000 kv-a. and with stator cores up to 10 ft. in length. The original method provided only two paths at each end of the machine, but about 1910 we began constructing machines with 6 paths at each end somewhat similar to that shown in Fig. 2, except that the vent segments were arranged to by-pass part of the air back of the teeth by making the vent ribs in suitable curved form. In the more recent large machines there are 12 paths at each end of the machine, which with a 72-slot punching gives three teeth opposite each inlet and three opposite the corresponding outlet.

To my mind, the outstanding advantage of the radial system of ventilation lies not so much in the particular arrangement of the parts, but in the fact that with either Method I or II it is possible to introduce cool air directly into the central part of the machine and thus cool this part almost as effectively as the end portions. In fact, tests show that with Method I suitably applied, the air discharged from the centre ducts is no hotter than that discharged from the ends. Further, we have not yet reached any limit to the length of the machine that can be ventilated by this method so far as stator ventilation is concerned. Mechanical features may limit the length and it might also develop that external fans would be needed in some cases, but so far as getting the air through the stator is concerned I believe satisfactory ventilation can be secured with the largest stators and by the use of either of the methods described.

After all, the real test of any given method of ventilation is the temperature rise in the centre of the machine as indicated by temperature detectors in the slots and with a sufficient number of such detectors to give indications all around the circumference. Recent tests on large units with ventilation as per Method I, using 12 paths, show that the temperatures are uniform and that there is no difficulty in building large machines with this system of ventilation that will show a temperature rise as indicated by detectors well within 60 deg. cent. The real limitation of large units thus becomes one of rotor rather than stator heating, but the low stator temperature rise possible with the radial system is a distinct advantage, as it reduces the chances of trouble due to expansion and contraction.

An incidental advantage of Method I is that it can be worked out so as to give a very simple and compact construction of the stator yoke. However, this has no bearing on the method itself which our experience indicates gives very uniform cooling with low end-bell pressures.

C. M. Laffoon: I desire to say a few words on the general subject of ventilation for large capacity turbo-generators. At the present time one or two of the larger electrical manufacturing companies are building 12,500-kv-a. 3600-rev. per min. and 43,750-kv-a., 1800-rev. per min. turbo generators for 60-cycle operation.

There is no doubt but that the trend in generator sizes is decidedly upward, on account of the fact that central stations are rapidly increasing in size, and there is a consequent demand for greater generator output per unit of floor space.

In addition to this, the operating companies and purchasers of large capacity units are demanding machines with low temperature guarantees, in the neighborhood of 80 deg. or less, in some cases 60 deg., depending upon the type and quality of the insulation used on the electrical conductors.

It is obvious from these facts that the question of the proper choice of a ventilating system and the predetermination of the temperature rises for any chosen turbo system are of vital importance to both designing and operating engineers. As has been suggested several times this morning, the system of ventilation which should be used is the one in which a permissible amount of cooling air can carry away the generator losses with a minimum and fairly uniform temperature rise throughout the entire machine, provided, that this system of ventilation is not so complicated as to handicap the cost of the machine, and that some efficient, reliable and stable means can be obtained for delivering the air to the different parts of the generator.

Regardless of the type of ventilation that is used, it becomes necessary in large capacity turbo-generators, to resort to the multiple path system. That is, the air must be delivered to machine at several different axial positions, in order to make a machine economical from the standpoint of cost and to assure a reasonably uniform temperature distribution. Some form of the radial systems that have been discussed here this morning is particularly applicable to machines with low temperature guarantees, because, as has been said before, large volumes of cool air or other cooling medium can be introduced into the machine in the tooth zone where the combined loss per unit volume is inherently high.

As you know, the American practise has always been, in large generators, both water-wheel and high-speed and 25-cycle turbo-generators, to use the radial system of ventilation. The radial system of ventilation is becoming quite generally used by all of the manufacturing companies in this country in order to obtain the lower temperature guarantees. With the radial ventilating system, the air can be presented to the paths at varying pressures, or can be taken into the end bell at constant pressure, if the paths are so designed and proportioned that the air will properly distribute through the machine and give fairly uniform temperatures. However, in either case the problem of actually designing the pressure-generating system for the air or the proportioning of the air paths and the number of passages that are provided, has been very difficult on account of the complexity of the problem and the lack of information available on the subject. The two papers by Messrs. Bratt and Fechheimer mark a definite advance in the published information on the subject of ventilation, and the experimental data obtained from models, as well as from turbo-generators as actually built, should greatly aid and facilitate the solution of this design problem.

It is true that machines using the radial system of ventilation have been built in the past by all of the companies in this

country without the aid of this particular information. However, there is no question but that by the use of these data which have been presented here and the mathematical analysis, more comprehensive and more intelligent designs should be made with less trial. The formulas and data as given in these papers are not simplified so that they can be readily used by designing engineers. However, they can be so simplified, so arranged and modified, that they should prove a source of valuable use to engineers who are responsible for the design of large turbo-generators.

F. D. Newbury: Mr. Williamson referred to his successful use of the circumferential system of ventilation. As I was very careful to point out in presenting the paper, the system of Model I is not exactly the same as the system actually used in practise, and furthermore, I wish to emphasize that our tests have no necessary relation whatever to temperature results. We simply attacked one part of the ventilation problem, and if our results have any value, they are valuable in showing relative performances of these two systems, and what may be expected in limiting cases.

Mr. Williamson also referred to the axial system of ventilation. That is a system that was, and has been, and is being very extensively used. It has been used very successfully, but it has the limitation that Mr. Williamson pointed out: that with very long machines, the length of the path through the machine is such that the rise in air temperature may become a serious disadvantage. So, in comparing the results from the first model and the second model, we only wish to draw the conclusion that Model II, representing the multiple radial system, seems to have advantages over the circumferential system of Model I, principally in a more uniform distribution of air, circumferentially, and a substantially uniform distribution of air axially, and in fact a very much better distribution of air axially than in the simple radial system, which is in such extensive use.

Mr. Knowlton referred to an experience of his own in connection with a very considerable increase in total volume of air when the entrance at the air gap was increased by cutting back several of the first packages. If you will refer to Figs. 34 and 35, I believe, of Mr. Fechheimer's paper, you will notice that although the air entrance was increased from one inch in Fig. 34, to one and one-half inches in Fig. 35, the total volumes are substantially equal. That illustrates, I think, the real value of these papers—that by confining the work to a particular phase of the problem, confining it to the measurement of pressures and volumes, under various conditions, and not complicating it with temperature results or loss results, we can definitely say that such and such a thing will happen when such changes are made in the ventilating circuit.

Mr. Knowlton also referred to the device illustrated on next to the last page of the paper, which he referred to as the "toy balloon." That, I think, is a very ingenious experimental device—I can say that because I had nothing to do with it—and it was used, as Mr. Knowlton suggested, in order to completely close up the ventilation duct and thereby enable the pressure to be measured without any velocity head being present.

Mr. Henderson referred to the actual use of the results from this work in practise. I think the first impression from these papers is that the numerical calculation work is complicated. Even if that is so, the results obtained from the application of Mr. Bratt's formulas are exceedingly valuable and the work involved is well worth while. Since the results have been available within the last 12 months, the work has been applied to some million kv-a. in turbo-generators, but in that large volume only seven different sizes have been involved; so you can well afford to spend considerable time and work in properly proportioning the ventilation system of a design, when it does involve so much in the way of risk and money and is of such importance in the results to be obtained from the design.

C. J. Fechheimer: It appears that comparatively little was brought out in the discussion to which I need reply. Mr. Knowlton has called attention to the fact that he was able to increase the quantity of air nearly in proportion to the increase in the area of the entrance to the air gap. Perhaps a comparison of Figs. 34 and 35 in my paper would bear upon Mr. Knowlton's experience. As I understand it, Mr. Knowlton cut back the first packages much as indicated in Fig. 35. According to our volume-meter readings, the total volume of air for all the paths was not changed a great deal, but the distribution of air, particularly for the vent ducts near the end bell, was modified very materially. Undoubtedly, had we been feeding this first section only, the volume-meter would have indicated a considerable increase when the first packages were cut back. The loss at entrance to the air gap expressed as a percentage of velocity head has lowered appreciably by the gradual reduction in section of the air gap. This would be evident to any one who is familiar with a bell-mouth entrance to a duct, which this condition approaches. The fact that the volume-meter did not show more of an increase was in part due to the fact that only a fraction of the total volume of air entered the air gap direct from the end bell, and to some errors in observation. A rather cursory examination of the average values of anemometer readings for Figs. 34 and 35 would not show very great differences.

Mr. Knowlton also mentions that he measured minus ¾ in. pressure on one side of the coil and plus 1.5 in. on the other side of the armature coil in a salient pole alternator. I have obtained from Mr. Knowlton a sketch showing positions in which

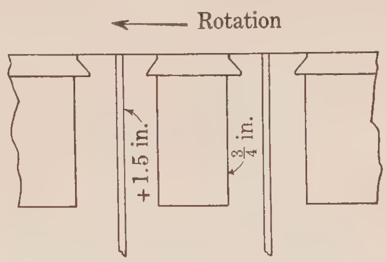

Fig. 3

the readings were taken, and this sketch I am reproducing herewith. There are undoubtedly so many things that enter into measurements of this kind that may mislead one, that it is impossible for me to offer a complete explanation. I can only suggest reasons for the difference. The air leaves the rotor at a slight angle with the periphery, and on the right-hand side of the coil it impinges on the slot wedge so as to destroy nearly all of the velocity head. What air then passes into the vent duct moves past the sharp edge of the wedge beyond which there is a "vena contracta," accompanying which there is usually a considerable reduction in pressure. If the pressure tube had been placed near this "vena contracta," it is easy to understand that the reading would be negative. On the other side of the coil, the volume of air flowing is probably more because all of the velocity head of the air as it leaves the rotor is not destroyed, and it is possible that the pressure tube was placed in such a position that the air impinged upon its opening. Consequently, the reading on the manometer would have been the static pressure plus the velocity head or a fraction thereof.

Of course, on this side, as on the other, there may have been a contraction in section beyond the edge of the wedge, but if the pressure tube were placed, say near the narrow section where the velocity head was greatest, and just before the "vena contracta," it is easy to understand why the reading was + 1.5. I might offer a number of other explanations, but this much is certain—that readings of this character are liable to be very misleading, and considerably in error. That was why we used the "toy balloon" method. The mouth of the brass tube which connected with

the manometer was about 3 in. from the air gap, and we felt quite confident that disturbances due to velocity would have negligible influence. Even so, we found discrepancies when the tube was placed on the side of the coil, corresponding to the side where Mr. Knowlton obtained — ¾ in. Our final readings were taken on the other side of the coil, and apparently then we were in a region which was quiet. I believe the picture of what takes place is clarified somewhat by thinking of the moving air streams at very high velocities—as though they were water—and imagining them to splash up into the duct as a result of disturbances in the high velocity stream.

The whole subject of ventilation or air flow is an extremely complex one. It is believed that the work which has been done up to date is only a small part of what may be done, and we hope that others interested in the problem will contribute papers from time to time before technical societies, which will assist the engineering public in solving some of our difficult problems.

Donald Bratt: There is one question that Mr. Knowlton brought up. He spoke of an instance in which he had noticed, in a radial type of flow, that some of the velocities in the extreme end came out negative; that is, the air was actually traveling the other way to what was intended. That is, in fact, the result that we very often find in the flow of air and flow of water in pipes. Sometimes, where a cross-section area changes considerably from a large to a small value, there will be a contraction in section of the jet of water or air, and a very low static pressure. The same thing may actually happen in a radial ventilation system. We have observed in Model II, in many instances, that the flow actually was reversed.

I have not, of course, been able to take care of that sort of condition in my mathematical analysis. It isn't of much importance anyway.

BRUSH MOUNTING AS A FACTOR OF SATISFACTORY OPERATION[1]

(Jones)

Philadelphia, Pa., February 8, 1924.

R. F. Franklin: I wish to discuss two points concerning Mr. Jones' paper. One is the criterion of zero box pressure; the other, the mathematical analysis of the brush forces.

The condition of zero box pressure which Mr. Jones strives to obtain, will not give satisfactory operation in practise since the slight variations of commutator friction for different points on the commutator will cause the brush to move back and forth in the box and chatter. Practical operation requires a brush angle which will insure the brush always bearing against one side of the box. However, the "box reaction" involved in this condition should not be great enough to prevent free axial movement of the brush in the box. The proper brush angle, therefore, is not the one that will give zero box pressure, but the one that will give a box pressure sufficient to hold the brush in contact with the box for all values of commutator friction and yet not so large as to prevent free axial movement of the brush.

Mr. Jones is correct in his assertion that the brush angle for reversible motors must be a compromise between that best suited for leading and trailing operation. For equal box reaction, the "lower brush angle" for the trailing brush is greater than that for the leading brush, because the tangential friction force in the former case adds to, and in the latter subtracts from, the tangential component of the axial force, $T \sin\beta$ (See Fig. 1). A compromise brush angle for reversible operation would, therefore, give increased box reaction for trailing operation and decreased box reaction for leading operation. If the friction force F becomes greater than the tangential component of $T \sin\beta$, the brush is dragged to the opposite side of the box during leading operation and will acquire what is called a "double fit," *i. e.*, one part of the brush face will be in contact with the commutator for one direction of rotation and another part of the face for opposite rotation. Definite pressure against one side of the box at the top during leading operation can be assured by beveling the top of the brush slightly so that a component of the spring pressure acts against the box.

The other point I wish to discuss is that of the author's analysis of the brush forces. The box reaction cannot be considered as acting at one point near the center of the brush since the contact surface between the brush and the box is a plane. Brushes which have been in service always show wear or polish which indicate that the box reaction is concentrated in a narrow area at the extreme bottom of the box. The method of taking moments, therefore, is incorrect. Instead, the forces acting should be resolved into components acting along and perpendicular to the axis of the brush. Thus the box reaction may be represented by two forces, as shown in the accompanying Fig. 1; force H_1 near the top of the box, due to the spring pressure, and H_2 near the bottom of the box, due to the result of commutator reaction and friction.

The analysis of the forces then becomes very simple. Thus the expression for the forces acting along the axis of the brush for the case of a leading brush, as shown in Fig. 1, is

$$T \sin\beta = P \sin\alpha + F \cos\alpha \qquad (1)$$

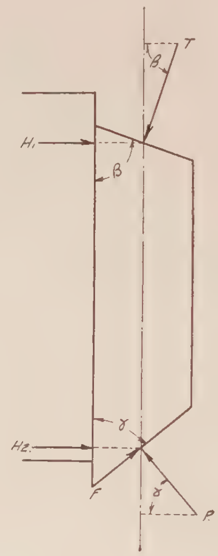

Fig. 1

The reaction at the top of the box is

$$H_1 = T \cos\beta \qquad (2)$$

and the reaction at the bottom of the box is,

$$H_2 = P \cos\alpha - F \sin\alpha \qquad (3)$$

Substituting the well-known relation $F = f P$, where f is the coefficient of the friction between brush and commutator, in (1) and (3) the following relations are obtained;

$$T \sin\beta = P (\sin\alpha + f \cos\alpha) \qquad (4)$$

and

$$H_2 = P (\cos\alpha - f \sin\alpha) \qquad (5)$$

The equations for the trailing brush are obtained by reversing the sign of the friction force. Thus for the trailing brush,

$$T \sin\beta = P (\sin\alpha - f \cos\alpha) \qquad (6)$$

$$H_1 = T \cos\beta \qquad (7)$$

$$H_2 = P (\cos\alpha + f \sin\alpha) \qquad (8)$$

If a square top brush is assumed (β = 90 deg.) the force equations (2), (4), (5), (6), (7) and (8) can be written in the form,

1. A. I. E. E. Journal, Vol. XLII, December, p. 1318.

$$\frac{T}{P} = \sin\alpha \pm f\cos\alpha$$

$$H_1 = 0$$

$$\frac{H_2}{P} = \cos\alpha \mp f\sin\alpha$$

where the upper signs are for the leading brush and the lower signs the trailing brush. These equations are plotted in Fig. 2 for the average value of $f = 0.268$ assumed by Mr. Jones. The

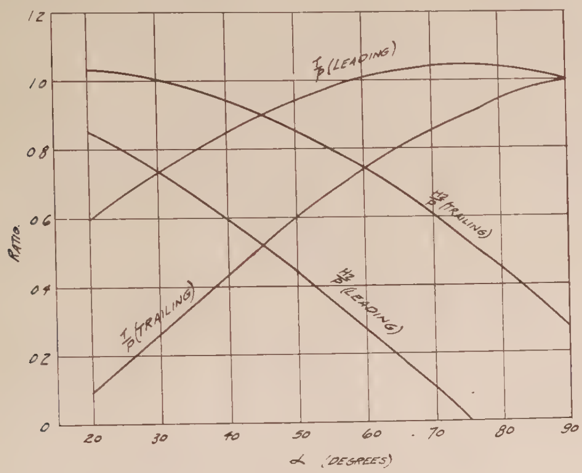

Fig. 2

curves in this figure should be compared with those of Fig. 5 in the paper.

P. D. Manback: Mr. Jones has presented a very interesting phase of the subject of brush application and one which probably has not been given enough consideration in the past. However, we have made this question the subject of considerable investigation and experiment for some time past. I think the mathematical deductions are very enlightening but may very easily lead one astray when making practical applications of these principles.

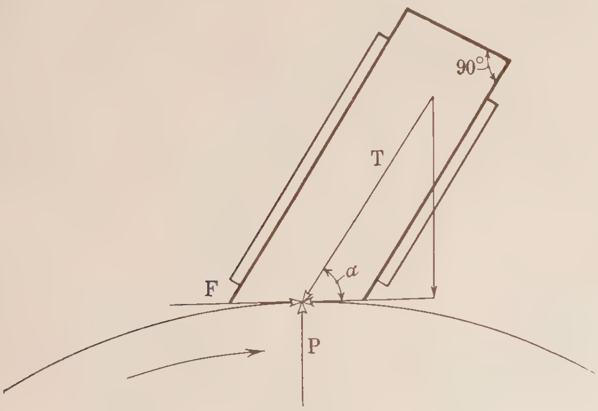

Fig. 3

It may be true that the weight of the brush need not be taken into account when calculating brush pressure in the case of carbon brushes, but in dealing with metal graphite brushes the weight of the brush is quite considerable and must be taken into account when calculating brush pressure. Also it may be ideal from a theoretical standpoint to operate a brush in a leading position with a commutator bevel of 75 deg. and top angle of 90 deg., but our experience has shown this usually to be bad practise. In the case just cited, the brush is floating in the holder and the side thrust is zero. This means that the force of friction just overcomes the tangential component of the spring tension. If the frictional force were absolutely constant, the practical case would approach the theoretical very closely, but this is not always true. Some parts of the commutator are not as highly polished as others, so that at one instant the friction may overcome the tangential component of the spring tension, while in the very next instant the friction may be less than the tangential component, thus giving rise to a pronounced brush chatter, harmful to commutator and brushes alike. It has been the object and aim of the brush manufacturer to keep away from this so-called critical angle so as to eliminate the undesirable element of chatter.

It has been found that a very definite relationship exists between the coefficient of friction and this critical angle. This relationship is derived as shown in Fig. 3.

If F, the force of friction, is just equal to the tangential component of the spring tension, then $F = T\cos\alpha$ where T = spring tension. $F = fP = fT\sin\alpha$ then $fT\sin\alpha = T\cos\alpha$ or

$$f = \frac{\cos\alpha}{\sin\alpha} = \cot\alpha$$

Since T, the spring tension, cancels out of the equation, it shows that the relationship holds true regardless of the magnitude of the spring tension, which agrees with practise. If we know the coefficients of friction of various brush grades, this simple relationship enables us to calculate the critical angles which should be avoided for satisfactory operation when the top angle of the brush is 90 deg. It must be taken into account, however, that the coefficient of friction will vary within certain limits, due to irregularities of commutator surfaces.

W. C. Kalb: I might mention that there is one statement in the early part of Mr. Jones' paper which I don't believe conveys quite the meaning he intended, where he says that the resistance of the contact between brush and commutator is proportional to the pressure perpendicular to the plane of contact. He is speaking, as I understand it, of the electrical resistance. Of course, that relationship is inverse.

In his presentation of this subject Mr. Jones has brought out some very interesting factors. It might be said, however, that too much emphasis has been laid on the importance of keeping the resultant force H at an extremely low value and its location central between the top of the brush and the lower edge of the holder. This suggests the approach of this problem from a slightly different point of view and its simplification by the elimination of the angle ψ.

It will be noted that the line of T in Fig. 2 of Mr. Jones' paper meets the line of F at an angle of $\alpha + \beta - 90$. If tangential and radial forces are resolved on the basis of this angle and the angle α, we have

$$P = T\sin(\alpha + \beta - 90) + H\cos\alpha \qquad (1)$$

and

$$F = T\cos(\alpha + \beta - 90) - H\sin\alpha \qquad (2)$$

or

$$P = H\cos\alpha - T\cos(\alpha + \beta)$$

$$F = T\sin(\alpha + \beta) - H\sin\alpha = Pf$$

When

$$H = 0$$

$$f = -\tan(\alpha + \beta)$$

but this would not be a stable brush position, hence $-\tan(\alpha + \beta)$ must be greater f.

This condition must hold at the moment of starting as well as during the running period, otherwise the brushes may be rocked from their position by the high static friction encountered at that instant. The coefficient of static friction may be as high as unity on a brush with normal running friction. So $-\tan(\alpha + \beta)$ should be greater than 1 and $\alpha + \beta$ should therefore be less than 135 deg.

When the machine is running, it is not sufficient that balance of forces maintain the resultant force H slightly above zero. Freedom from chattering is only attained when the component

of the force P normal to the side of the holder exceeds the like component of the force F.

That is, we should have

$$P \cos \alpha > P f \sin \alpha$$

or

$$\cot \alpha > f$$

While 0.4 is rather high as a coefficient of friction for a good grade of brush at proper tension, Mr. Jones has shown that it is a figure which may be encountered and therefore the design of the brush holder should be such as to accommodate a brush with this coefficient of friction. $\cot^{-1} 0.404 = 68$ deg., indicating that a larger angle at α is not desirable.

That the limits here suggested are reasonable is supported by the following illustrations from service conditions:

Standards that operate well,

$\alpha = 60$ deg., $\beta = 60$ deg., $\alpha + \beta = 120$ deg.
$\alpha = 60$ deg., $\beta = 50$ deg., $\alpha + \beta = 110$ deg.
$\alpha = 52\frac{1}{2}$ deg., $\beta = 75$ deg., $\alpha + \beta = 127\frac{1}{2}$ deg.

A standard that does not operate well,

$\alpha = 70$ deg., $\beta = 90$ deg., $\alpha + \beta = 160$ deg.

The foregoing discussion is confined entirely to a consideration of leading operation. We are in full accord with Mr. Jones in recommending leading in preference to trailing operation.

Philip Chapin Jones: Mr. Franklin points out that zero box pressure would not be saitsfactory in practise. In my paper I stated merely that "the *ideal* condition would be to make the side thrust zero." I had no intention of recommending it as good practise for the very reasons which Mr. Franklin mentions. As a matter of fact, I find in practise that a value of 75 deg. for β and 60 deg. for α works very satisfactorily.

The second point Mr. Franklin raises I do not believe is quite correct. In undertaking a mathematical investigation of physical phenomena it is necessary to assume certain ideal conditions and then in practise to make such allowances as will provide for a deviation from the ideal conditions. Thus, in this brush analysis I have assumed tacitly that we are dealing with plane surfaces both on the brush and in the holder. Under this assumption any force applied to the brush will react on the holder, not at a point or on a line but over the entire surface of the brush. For the purpose of taking moments, however, it is perfectly correct to consider a resultant force applied at some one point which is the center of gravity of all the differential pressures acting over the entire surface. In case there is no resultant turning moment on the brush, this point of action of the resultant pressure will be in the center of the surface. Inasmuch as I have so taken the various brush angles that there will be no resultant turning moment, the resultant force in the case I am discussing in the paper will be at the center of the surface.

Mr. Franklin's statement that "brushes which have been in service always show wear—in a narrow area at the extreme bottom of the brush" is too broad to be strictly true. This evidence of wearing at the bottom of the brush, however, is merely an indication that there is a turning moment acting on the brush.

Mr. Franklin's division of the box reaction into two forces H_1 and H_2 is arbitrary and entirely unnecessary as long as he is only dealing with components parallel and perpendicular to the axis of the brush. He would have had exactly the same resultant equations had he used only one H no matter at what point he applied it. It is impossible to compare curves drawn from his equations with my Fig. 5 as his equations correspond to only one point on my curve for leading brushes and to none on my curve for trailing brushes. Fig. 5 is plotted, as noted in the text for the condition that $\beta = \alpha + \psi$ where ψ (equal to 15 deg. in this case) is positive for leading brushes and negative for trailing brushes. Mr. Franklin starts by assuming that β is 90 deg. which at once fixes α as 75 deg. for leading brushes under my assumptions.

In my first investigation of this subject I did exactly as Mr. Franklin has but I soon found that I was not covering the subject and that my equations were indeterminate. In my final analysis, therefore, as given in this paper I use moments first to insure a radial movement only of the brush and then use force componants to get the relations between the various forces.

Mr. Manback's remarks call for no further comment from me. In replying to Mr. Franklin's first point I pointed out that I had no intention of recommending this condition of zero box pressure as the best practical value.

My statement of contact résistance to which Mr. Kalb refers is, I believe, strictly correct but the proportionality, of course, is inverse and not direct.

As regards the second section of Mr. Kalb's comments, I have little to say. Apparently my paper has given the impression that I was recommending a zero box pressure, while as I have pointed out previously, I was merely indicating that as an ideal limit which could never be reached in practise. The values I do recommend, of $\alpha = 60$ deg. and $\beta = 75$ deg. would, I believe, meet with Mr. Kalb's approval and they also satisfy the other requirements as pointed out in my paper.

THEORY OF THREE CIRCUIT TRANSFORMERS[1]

(Boyajian)

Philadelphia, Pa., February 8, 1924

P. L. Alger: Mr. Boyajian's theory of three-circuit transformers applies to the induction motor as well as to the transformer. His three-circuit transformer is the same in theory as the double-squirrel-cage induction motor, and the same phenomenon of a negative reactance which occurs in his diagrams also occurs in the equivalent circuit of the motor.

It is very interesting to review these analogies which occur between related branches of engineering and utilize them in extending one art to keep up with the others. I believe that this paper of Mr. Boyajian's may be of material assistance in extending our knowledge of the complicated phenomena of the multiple squirrel-cage induction motor.

H. L. Cole (by letter): The subject of multiple winding transformers is becoming of greater importance as the networks of power systems increase in number and size. Up to the last few years it has been of importance mainly to the design engineer, by whom the various loading and short-circuit conditions have to be studied in order that such special transformers will meet the electrical, mechanical and thermal conditions imposed upon them in service. The large number of applications of multiple winding transformers in recent years has shown the necessity of studying the relation of the transformer impedances to those of the rest of the system to which it is connected, as brought out by Mr. Boyajian. The paper covers a large field of study, and will prove a useful reference on the subject.

In Appendix E (V) there is one case of short-circuit conditions in which I do not entirely agree with the author's analysis. Equation (**46**), which gives the impedance between system A and circuit C as

$$Z_{AC} = 2/3\ Z_{ab} + 1/3\ Z_{bt} + 2/3\ Z_A$$

should be $Z_{AC} = 2/3\ Z_{ab} + 2/9\ Z_{at} + 1/9\ Z_{bt} + 2/3\ Z_A$

In this way, the effect of the impedance Z_{At}, which is a factor in limiting the current in circuit C, is taken into account.

A. Boyajian: I have checked and reaffirmed the correctness of the equation (**46**) which Mr. Cole has criticised. I am afraid that the alternative equation which he offers is in error.

My equation is given in a form suitable for all interleaved transformers (whether shell or core type), irrespective or whether the tertiary is between the primary and secondary or outside. The equation which Mr. Cole offers is in a form which I believe presupposes a definite location for the tertiary. If we correct the first term of his equation, changing it from $2/3\ Z_{at}$ into $4/9\ Z_{ab}$, it will fit the case of an external tertiary, and is then reducible into my equation. Thus, referring to the attached sketch, and making use of the principle that reactive kv-a.

1. A. I. E. Journal, Vol. XLIII, April, p. 345.

consumed, varies as the square of the current (as explained and illustrated in my paper), we get the following results:

(1), Since the density in the gap between a and b, on the vertical phase, is $^2/_3$ normal, the reactive kv-a. consumed thereby will be $4/9\ Z_{ab}$; (2) the density between b and t, on the vertical phase, is $1/3$ normal, and therefore the reactive kv-a. consumed thereby will be $1/9\ Z_{bt}$; (3), on the other two phases between a and t the density is $1/3$ normal, the reactive kv-a. consumed in each is $1/9$ normal, and therefore for the two legs we have $2/9\ Z_{at}$. Adding these three items, the effective reactance of the transformer itself, exclusive of that of generating system A, will be,

$$Z_{eff} = \frac{4}{9} Z_{ab} + \frac{2}{9} Z_{at} + \frac{1}{9} Z_{bt}$$

This equation differs from that of Mr. Cole in the coefficient of the first term, having 4/9 instead of 2/3, and is reducible into equation (**46**). Thus, since

$$Z_{at} = Z_{ab} + Z_{bt}$$

to a very close approximation; making this substitution,

$$Z_{eff} = \frac{4}{9} Z_{ab} + \frac{2}{9} (Z_{ab} + Z_{bt}) + \frac{1}{9} Z_{bt}$$

$$= \frac{2}{3} Z_{ab} + \frac{1}{3} Z_{bt}$$

which is equation (**46**), less $2/3\ Z_A$, the impedance of the generating circuit.

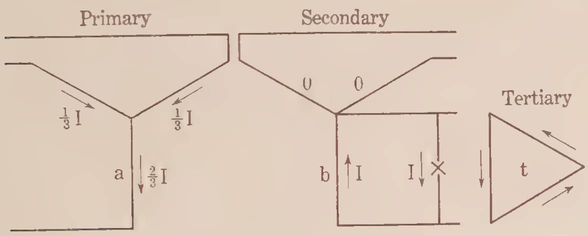

Fig. 1

If the tertiary delta be assumed located between primary and secondary, as shown in Fig. 24 of the paper, we get: (1), on vertical phase, between a and t, $4/9\ Z_{at}$; (2), between b and t, Z_{bt}; and, (3), in the other two phases, $2/9\ Z_{at}$. Adding these three items,

$$Z_{eff} = \frac{4}{9} Z_{at} + Z_{bt} + \frac{2}{9} Z_{at}$$

$$= \frac{2}{3} Z_{at} + Z_{bt}$$

But, $Z_{at} = Z_{ab} - Z_{bt}$. Hence, making this substitution,

$$Z_{eff} = \frac{2}{3} Z_{ab} + \frac{1}{3} Z_{bt}$$

which again is equation (**46**), less $2/3\ Z_A$, the impedance of the generating circuit.

Equation (46) being thus applicable to a very close approximation to the case of the inside as well as of the outside tertiary, it is applicable in general, and is desirable on account of its simplicity. It is also evident that Z_{at} enters into the equation indirectly, in terms of Z_{ab} and Z_{bt}, by virtue of its relationship to them.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

FUNDAMENTALS OF LIGHT AND VISION

By Ward Harrison

The well-lighted plants and offices of today are proving that good illumination is very much worth while. Industrial managers, foremen, and executives are beginning to realize that good illumination removes the handicaps which accompany poor lighting, and enables their employees to work more rapidly and more accurately. This increased production of a more accurate nature results from the fact that the eye is able to function with greater rapidity and comfort under the higher levels of illumination.

Good artificial illumination is a development of comparatively recent years, and although it is quite generally conceded to be desirable, there are few who entirely comprehend how the accompanying benefits are derived. The following curves present basic facts which provide a direct link between better illumination and the increased production which has invariably resulted.

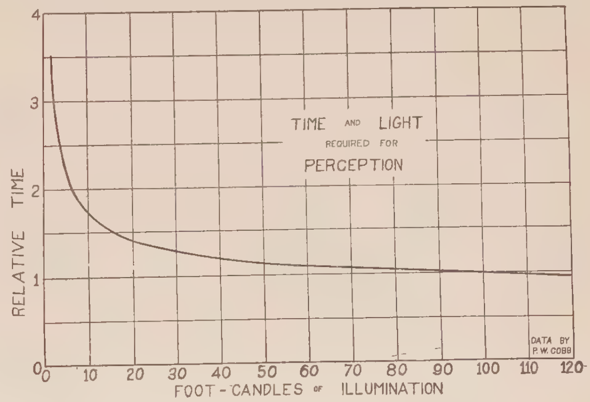

Fig. 1

Fig. 1 shows the relation between the level of illumination and the simplest visual operation—perception. This curve illustrates the outcome of a series of tests in which a black dot was exposed momentarily on a white field, and for each level of illumination the shortest exposure was found for which the subjects could recognize the mere presence of the dot. The curve shows that the time required for perception become materially greater as the illumination is decreased below 100 foot-candles, which corresponds to the outdoor illumination on a very dark cloudy day. The usual range of outdoor illumination to which the eye has become accustomed through centuries of evolution is about 500 to 10,000 foot-candles.

Good vision requires more than the mere perception of an object; it requires the discrimination of its fine details as well. The speed with which this discrimination can be accomplished—or in other words, the speed of vision—involves all factors of light and lighting which influence the ability of the eye to distinguish differences in brightness, color and fine detail. Tests, similar in

character to the "perception" tests, have been conducted on the relationship between the time required for discrimination and the level of illumination; the results obtained show the same general trend as that noted in the curve of Fig. 1. Thus the eye discriminates details more rapidly under the higher levels of illumination, although requiring more time than for mere perception. In a measure, the time required for discrimination determines the rapidity of bodily movement in operations such as those involved in the use of mechanical devices for billing or computing and the like.

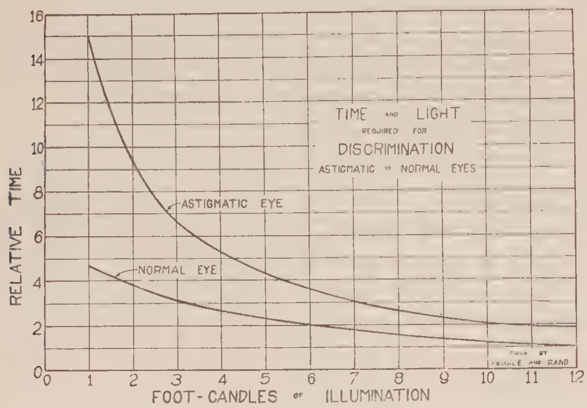

Fig. 2

In the case of the astigmatic eye, the time required for discrimination is even more dependent upon the level of illumination. This is shown very clearly by the curves in Fig. 2. These curves are confined to the range of illumination values in which the speed of discrimination changes most rapidly. Thus at the lower levels of illumination the astigmatic eye is handicapped to an even greater extent than the normal eye. Conversely, an increase in illumination benefits the astigmatic eye to a relatively greater extent than the normal eye. This fact is especially worthy of note because statistics have shown that more than half of the industrial workers of today have defective vision.

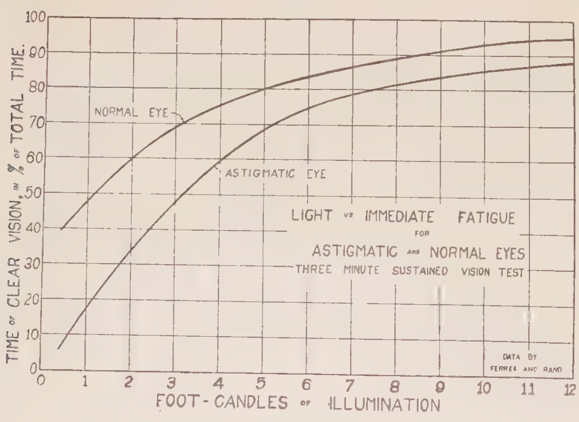

Fig. 3

It is a common experience that under a fixed gaze the eye will become fatigued to such an extent that the detail in an object gazed at will become blurred. Tests which establish this fact have been conducted which give results such as shown in Fig. 3. Here again the astigmatic eye is handicapped even more than the normal eye by insufficient illumination. As shown by these curves, a fixed gaze fatigues the eye much more rapidly when the illumination is inadequate, and defective vision also seems to aggravate this condition.

Brightness contrast is another factor which exerts an influence on the speed of vision. Recent tests on the speed of reading involve both discrimination and brightness contrast in a manner similar to that encountered in office work and the like. Fig. 4 contains the results of two such tests, which again demonstrate the fact that the speed of vision is lessened by inadequate illumination and that it also varies with the degree of contrast of an object with its background.

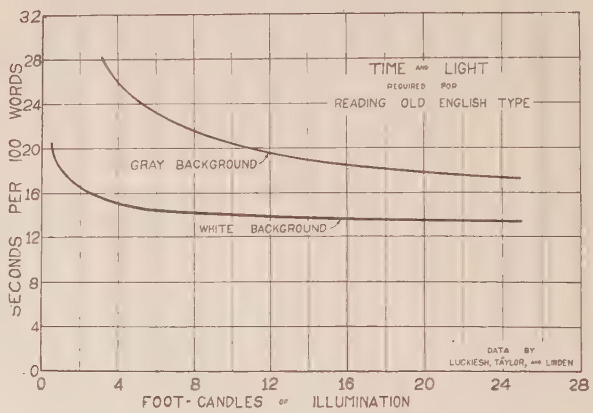

Fig. 4

This latter fact is significant, since in the everyday use of the eye, with the single exception of the printed page, brightness contrasts are seldom found as pronounced as black or white, which is the best condition for visual acuity.

The actions of the human body depend very largely on fundamental visual operations. Consequently, when the speed of vision is retarded in any way, the bodily movements depending on vision become necessarily slower and more uncertain. Thus under conditions of poor illumination, the production of an industrial worker may be decreased considerably, and conversely, good lighting enables the eye to see quicker, thus permitting more rapid production. These fundamental facts explain why actual factory tests have shown that good illumination is by no means a short lived stimulant.

The question of rating storage batteries for radio service has been under discussion among various manufacturing companies and the advertising clubs. The need for standardized ratings for these batteries is recognized throughout the industry since many batteries now being sold are obviously over-rated. No formal action has, however, been taken in this matter.

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The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Midwinter Program to Feature Machinery, Transmission, Physics, Communication

The coming Midwinter Convention to be held in New York, February 9-12, promises many attractive sessions. As usual in a midwinter meeting machine design will be prominently featured and of equal importance will be the sessions on transmission, electrophysics, electrical measurements and communication. Electro-chemistry and statistics will be represented by at least one paper each.

A smoker, an evening with a special meeting, a dinner-dance and inspection trips will constitute the social or non-technical events in the program.

The following papers, while not finally adopted, are being considered for presentation.

PAPERS CONTEMPLATED FOR MIDWINTER PROGRAM

Machinery

A New A-C. General-Purpose Motor, H. Weichsel, Wagner Electric Corporation.

A. C. Commutator Motor Design, L. W. Perkins, Westinghouse Electric & Mfg. Co.

The Effect of Full-Voltage Starting on Induction Motors, J. L. Rylander, Westinghouse Electric & Mfg. Co.

Another Form of Self-Excited Synchronous Induction Motor, Val A. Fynn, Consulting Engineer.

The Thermal Time Constants of Electrical Machines, A. E. Kennelly, Harvard University.

Squirrel-Cage Induction-Motor Core Losses, Thomas Spooner, Westinghouse Electric & Mfg. Company.

Complete Synchronous Motor Characteristics, E. D. Engeset, R. H. Jones & J. F. H. Douglass, Marquette University.

Application of Motors to Mine Locomotives, W. C. Clark, Westinghouse Elec. & Mfg. Company.

Factors Affecting the Design of Direct-Current Locomotives, R. E. Ferris, Westinghouse Elec. & Mfg. Company.

Transmission

Power-System Transients, V. Bush and R. D. Booth, both of Jackson and Moreland, Engineers.

Studies of Transmission Stability, R. D. Evans and C. F. Wagner, Westinghouse Electric and Mfg. Co.

The Artificial Representation of Power Systems, H. H. Spencer and H. L. Hazen, General Electric Company.

Electrophysics

Study of Direct-Current Corona in Various Gases, F. W. Lee, Johns Hopkins University.

Effect of Repeated Voltage Application on Fibrous Insulation, F. M. Clark, General Electric Co.

Corona in Oil, A. C. Crago and J. K. Hodnette, Westinghouse Electric & Mfg. Co.

Stresses in Bus Supports during Short Circuit, O. R. Schurig and M. F. Sayre, General Electric Company.

Measurements

Electrical Measurements of Non-Electrical Quantities, Perry A. Borden, Hydroelectric Power Commission of Ontario.

Use of the Oscillograph to Measure Mechanical Phenomena, Harvey L. Curtis, Bureau of Standards.

Temperature Errors in Induction Watthour Meters, I. F. Kinnard and H. J. Faus, General Electric Company.

Testing Impregnated-Paper-Insulated Lead-Covered Cables, Cables Everett S. Lee, General Electric Company.

Communication

Voice-Frequency Cable-Carrier Telegraph System, H. Nyquist and B. P. Hamilton, American Telephone and Telegraph Co. and W. A. Phelps and M. B. Long, Western Electric Company.

Direct-Current Metallic Telegraph System for Cables, D. E. Branson and Mr. Schanck, American Telephone & Telegraph Co. and Mr. Bell, Western Electric Co.

Design of Distortionless Power Amplifiers, E. W. Kellogg, General Electric Company.

The Theory of Probability and Some Applications to Engineering Problems, E. C. Molina, American Telephone & Telegraph Company.

Miscellaneous

Storage-Battery Electrolytes, G. W. Vinal, Bureau of Standards.

Predicting Central-Station Demands and Outputs, F. C. Ralston, Philadelphia Electric Company.

Future Section Meetings

Boston

A Talk will be given by Professor J. H. Morecroft. December 9.

Fort Wayne

"Personnel Grading of Engineering Students," by Professor A. A. Potter, Dean of the School of Engineering, Purdue University. Moving pictures. To be held at the G. E. Club Rooms, Building 16-2, 8:00 P. M., December 18.

Philadelphia

"The Physical Properties of Speech, Music and Noise and Their Relation to Problems of Transmission," by Dr. Harvey Fletcher. December 8.

Pittsfield

"With MacMillan in the Artic," by Ralph T. Robinson, Chief Assistant to Donald MacMillan. December 16.

Vancouver

"Skagit River Power Development," by C. F. Uhden. December 5.

Papers for the Spring Meeting

Some definite plans have already been made for the Spring Convention which will be held in St. Louis during April. The subjects of power-station design and applications to industry which are of great interest to the engineers in the Middle West will be covered by capable authors in the technical sessions. In order that advance copies may be prepared in time all authors of papers for this meeting are requested to have their papers at Institute headquarters no later than January 15th.

Third National Exposition of Power and Mechanical Engineering

On December 1-6 the Third National Exposition of Power and Mechanical Engineering will be held at Grand Central Palace, New York City. Every kind of machinery and equipment for the generation and utilization of power and the development of the science of mechanical engineering will be shown.

Some of the leaders of the profession will give lectures on subjects of vital interest to the engineering world and films will also be shown. Exhibits both historical and modern will be an interesting part of the Exposition.

The Annual Meeting of the American Society of Mechanical Engineers will be held from December 1-4 in the Engineering Societies Building, and the American Society of Refrigerating Engineers will be held December 2-4 at the Hotel Astor, both associations having planned interesting technical sessions, but they have been so arranged that there will be no conflict with the lectures at the Exposition.

Third International Conference on Large Extra High-Tension Electric Supply Systems

Notice has been received, addressed to all the National Committees, from C. le Maistre, General Secretary of the International Electrotechnical Commission, calling attention to the Third International Conference on Large Extra High-Tension Electric Supply Systems, which will be held in Paris the latter part of June, 1925. It is hoped that each committee will give the Conference its utmost support. All communications in this connection should be addressed to M. Tribot Laspiere, Secretary, Union des Syndicats de l'Electricite 25, Boulevard Malesherbes, 25 Paris.

Following is the Agenda for this Conference:

Agenda for Third International Conference on Large Extra High Tension Electricity Supply Systems June, 1925

1st Section

Production and Conversion of Energy

A. Plant and Equipment of Central and Sub-Stations:
   - a. Alternators
   - b. Transformers
   - c. Switchgear
   - d. Insulators
   - e. Cables

B. Parallel working of central stations:
   - a. Difficulties encountered
   - b. Influence of the Characteristics of the circuits
   - c. Conditions to be realized
   - d. Solutions adopted

C. Division of load between stations

D. Characteristics of the auxiliary stations

E. Open-Air Sub-Stations

2nd Section

Construction and Insulation of the Lines

F. Relation between pressure, length of line, and the power to be transmitted

G. Arrangement of the lines

H. Poles:
   - a. Loading
   - b. Shape, dimensions, construction and erection
   - c. Strength of foundations

I. Insulators:
   - a. Shape, dimensions and tests
   - b. Fastenings
   - c. Endurance
   - d. Fixing of the conductor
   - e. Distribution of the voltage on the insulator units
   - f. Study of the raw materials

J. Conductors

K. Jointing of the underground cables to aerial lines

L. Experimental determination of the electric constants (self-induction, capacity, leakage, corona effects)

M. Underground and submarine lines:
   - a. Limit of the use of cables of one or more conductors continuous or a-c.
   - b. Determination of electric constants
   - c. Test after installation

3rd Section

Maintenance, Safety and Protection

N. Choice of transmission pressure. Standardization of Frequency

O. Regulation:
   - a. Frequency
   - b. Pressure
   - c. Phase displacement
   - d. Sudden change of flow

P. Excess current:
   - a. Purpose and use of induction coils
   - b. Relay coils
   - c. Short circuits to earth

Q. Excess Voltage:
   - a. Atmospheric
   - b. Internal
   - c. Earth connection of the neutral point
   - d. Protection of the insulators

R. Supervision:
   - a. Maintenance of the lines in good condition
   - b. Finding and localizing faults
   - c. Cutting a defective line out of circuit

S. Measurement of energy at extra high tension

T. Telegraphic and telephonic communications, ordinary and wireless

U. Administrative technical regulations. Their internationalization.

Southern Virginia Section Holds One-Day Meeting with Other Societies

The Southern Virginia Section of the Institute held a most interesting joint meeting with the other engineering societies of the State on October 17th, at Richmond, Va.

In the morning a trip was made to the new filtration plant of the City of Richmond. Two papers were read at the afternoon meeting. The first was by F. F. Harrington of the American Society of Civil Engineers and also Chief Engineer of the Virginia Terminal Railway, Norfolk, Va. He spoke on "The Equipment and Operation ot the Virginia Railway Coal Pier No. 2, at Sewalls Point." This is the largest and one of the most efficient and up-to-date coal piers on the Atlantic seaboard. The second paper at the afternoon meeting was given by Louis W. Sipley of the American Society of Mechanical Engineers, representing the Alfred J. Forschner Company of Philadelphia, Pa. Mr. Sipley gave a very interesting illustrated lecture on the subject of, "Material-Handling Industrial Trucks."

Dinner was held at the Commonwealth Club, Dr. Wm. M. Thornton, Dean of the School of Engineering, University of Virginia, acting as toastmaster. After dinner A. A. Northrop,

Construction Superintendent of Stone & Webster, Boston, Mass., read a paper on "Methods Used for Determining Unit Prices Based on Costs in the Construction Industry."

Two future meetings to be held jointly with the other engineering societies of Virginia have been scheduled, the first at Norfolk, Va., sometime during the month of January. This meeting is being arranged by the Hampton Roads Engineers Club. The second meeting is scheduled for the month of March at Virginia Polytechnic Institute, Blackburg, Va.

Meeting of Lehigh Valley Section Draws Attendance from a Distance

A very successful Section meeting in a territory of widely scattered membership was held at Pottsville, Pa., by the Lehigh Valley Section on November 21. The 270 who attended came from the surrounding neighborhood from distances up to 100 miles. The Lehigh Valley Section rotates its monthly meetings among the several towns in its territory and this is the second annual meeting of the Section held at Pottsville. W. H. Lesser, who had charge of the local arrangements, and J. L. Beaver, Chairman of the Section, deserve much of the credit for this successful gathering.

The speakers of the evening were G. N. Kennedy, Electrical Engineer, Lehigh Coal and Navigation Company, who talked on the development of electrification of the mines in the anthracite region; N. H. Reinicker, Superintendent of Operation, Pennsylvania Power & Light Company, who told how the light and power systems have developed and of the precautions taken to maintain service, and L. W. W. Morrow, Chairman, Meetings and Papers Committee, A. I. E. E., spoke on the scope and progress of the American Institute of Electrical Engineers.

Extracts from President Osgood's Address at the Pasadena Convention

"The Institute is always glad to come to California, or to any place in this section of the country because we feel that we have done a great deal towards its development and we enjoy partaking in the festivities which go with the development.

"It is not so far from here to the East. Only a few days ago I was in Troy, New York, with your famous engineer, Mr. Grunsky, President of the Civil Engineers, and heard him make a most charming address at the 100th Anniversary of Rensselaer. Then I came out here a few days later and saw all the friends from this coast whom I am used to seeing in the East. First, we had the railroad, then the telegraph, then the telephone, and the flying machine now brings you your papers the same day they are printed in the East, and it brings us news from you, so that surely we are a part of you out here. We are less than one day apart, less than a few moments, in case we want to speak to each other, and if we electrical engineers have brought this about, as much as any other group, we are certainly very glad to have helped in bringing about the truth that the East is West and the West is East.

"Now, gentlemen, it may be well to have just a little family talk this morning about some of the things that the Institute is doing. The thing that strikes my mind first is the splendid growth which this section of the country is having in its Institute membership. For example, five years ago the membership of the whole Institute was 10,252, and in 1924, at this time, it is 16,500. Referring to the California growth, five years ago the membership was 464, while today it is 888. So, you see you are exceeding the national growth itself which shows not only a healthy, but a gratifying situation.

"I wonder if any of you are familiar with the new movement in the Institute to develop district meetings. Last Spring we had the first district meeting at Worcester, Massachusetts. That meeting had almost the scope of a national meeting considering the character of the papers presented. It is highly important that we develop these district meetings for the reason that with a membership now of over 16,500 it is impossible to get to the membership the information that should properly come from so many minds and go to that number of minds. If we develop our district meetings to the importance, virtually, of national meetings, so that our first papers can be given at those district meetings, we shall have accomplished what seems best for the Institute at the present time in order to cover our field as it should be covered each year. So, when those of you who are here go back to your home sections, I wish you would carry that thought because it is very important, as the electrical engineers have so much to say now to each other and to the world.

"It is proper, I think, to mention the work that is being done by the Institute and in other societies, in a matter which I might call 'job service.' That is, finding positions for men who want them, and finding men for positions that want the men. For several years past the four founder socities have joined hands in the Engineering Building in New York in this service. As jobs are often interchangeable between the various lines of engineering and for the sake of economy we have combined this work. A certain sum of money has been set aside by each of the four societies for this work and the men who obtain positions through this bureau pay a slight fee. Any money that is left over will be used for the establishment, we hope, of joint offices in other large cities of the country, furnishing this same professional service. It is not with a thought of upsetting anything that is going on at the present time in this helpful movement that I make this announcement, but more with the thought to advise you what is possible, in the hope that we may have but one office in each centre for this very natural, helpful and dignified plan of gettngi professional men into their professional work.

"Just a word on the matter of research. I bring it up now because recently I had a splendid talk with Mr. Ambrose Swasey. He needs no introduction to you gentlemen as the founder of Engineering Foundation. He gave, initially, $100,000. He has increased that sum to $500,000, from time to time, and that is his personal gift for the purpose of engineering research. He calls it a nest egg, but that is somewhat of a misnomer, because it, in itself, is hatching well, but he meant that it should draw other eggs into the nest. There is a movement just starting, and it will naturally originate with Engineering Foundation, for the building up of this fund to a proper size. I should like to see it grow at this time to $20,000,000, which, at 5 per cent, would only give us a million dollars a year for research work. There will be a very determined movement, possibly in a few months, by the four founder societies in an effort to increase the fund. The Engineering Foundation itself will do no actual research work, but the Foundation is the custodian of the fund, having considerable to say as to how the fund shall be used and the four founder societies are virtually the children of the foundation who will carry on, through their respective committees, or the Engineering Research Council, or some other logical body, the research work needed for the nation. I give you this thought in the hope that you will make known the idea to industries and to anybody who should feel disposed to contribute when the right time comes.

"I was very glad to hear our Chairman say that there are engineers here in the City government of Pasadena. I think it is high time we got into civic affairs. I was very much impressed by the famous engineer from Italy, Senator Luiggi, who has been over here for some weeks. He tells us, if I remember the figures correctly, that there are thirty engineers in the Italian Senate, and fifty engineers in the lower house. He himself is a wonderful engineer and is engineering advisor to the Italian government. They seem to believe more in engineering in civic matters over there than here. In reply to that thought he said, 'Perhaps the engineers believe more in getting into civic affairs over there than they do here.'

"I wish the electrical engineers would get a new name for what is now called 'super-power.' That is a catch-title. 'Super-power' sounds perfectly splendid. The politicians have made everything they could of it. Certainly it brought the electrical industry into wide prominence. The ordinary citizens were expected to be able to understand the term 'super-power,' but it is really an unfortunate term because it does not mean what it says. It indicates that there is to be superimposed over the existing power systems something grand which will hold the thing together, or benefit the whole situation. That is not the case at all. There is nothing 'super' about it; it is merely the extension of transmission lines. I hope that the Institute as a whole can think up, not necessarily a new catch-phrase for it, but some useful words which will overcome the thought of a superimposed mysterious thing.

"We engineers, of course, have a very sincere duty. I think our duty is three-fold. We have, first the duty to engineering, which means that our work must ring absolutely true—that is the duty to our profession. It utilizes the advantage, to my way of thinking, of an engineering education. A man may be a banker, a merchant, or anything you please, other than an engineer, but an engineering education for him as a boy is going to be most helpful. Why? Because engineering deals in facts, not in opinions; an engineer is taught to think straight, and that habit will carry all through his life.

"Our second duty, as engineers, is to do what we should for our national society. In our case, this means the American Institute of Electrical Engineers. Our duty is to give to it all that we can, to build up through it the history of electrical engineering. That is why this Institute was formed forty-one years ago. Anything that is worthy of record should be recorded through our Institute, through papers. When you know something worthwhile do not hide it under a bushel; give it to the engineers and to the people at large.

"And, finally, I believe we have a duty as engineers to do all we can faster and better than we have been doing it to make progress in the world of electrical engineering, and particularly as we fit our art into the other specialties in engineering. No civil engineer can get along without us; we do most of his hoisting. No railroad man can get on without us, and even if he does not like electrification we do his signaling. No real mechanical man can get on without us; we have to drive his machines. And, of course, we cannot get on without ourselves. Therefore, besides our duty to our profession and to our Institute we have a very distinct duty in service for the help of our fellow-man, and for the betterment of the world."

Dr. Faccioli Speaks at Chicago on High-Voltage Phenomena

An unusual opportunity was afforded the members of the Chicago Section of the Institute in a joint meeting with the Western Society of Engineers on October 6th to hear an address by Dr. Giuseppe Faccioli, Chief Electrical Engineer of the General Electric Company at Pittsfield, Mass. The address was on the general subject of high-voltage phenomena and Dr. Faccioli explained in a very clear manner the generation and reflection of high-voltage waves with steep fronts and with high frequencies.

Dr. S. Z. de Ferranti Guest of Honor

The officers of the American national societies of civil, mining, mechanical, and electrical engineers arranged a luncheon in honor of Dr. de Ferranti at the Yale Club, in New York, on Thursday, November 6, which was attended by more than one hundred members of these societies.

Dr. Ferranti, whose work in the engineering and scientific fields is well known throughout the civilized world, is a Past-President of the Institution of Electrical Engineers and a member of the Institution of Mechanical Engineers, of Great Britain, and is also an Honorary Member of the American Institute of Electrical Engineers.

Mr. John W. Lieb, Past President of the A. I. E. E., presided and brief addresses were made by Mr. F. R. Low, President, American Society of Mechanical Engineers; Mr. Alex Dow, representing the American Society of Civil Engineers; Mr. J. V. R. Reynders, Vice-President, American Institute of Mining and Metallurgical Engineers; and Mr. Calvert Townley, Past President of the A. I. E. E. Dr. Ferranti in response gave an exceedingly interesting address, including some of his very early experiences in electrical engineering.

The occasion afforded an opportunity for the recognition by American engineers of the presence in the United States of one of the most eminent engineers of Great Britain, and for another exchange of courtesies between representatives of the various societies concerned—which all tend toward more cordial relations and continued closer cooperation of the engineers in this country and abroad.

NATIONAL RESEARCH COUNCIL

HIGHWAY RESEARCH

Chas. M. Upham, Director of the Highway Research Board has prepared a strong program for its fourth annual meeting to be held at Washington, Dec. 4-5. Among other important topics to be discussed, the question of defaulted highway contracts is looked upon as paramount, and it is believed that while many unforeseen elements may creep in, a more accurate calculation of the work by the contractor himself, might be representative of a saving of considerable time and money. The responsibility of the bonding companies was also considered, and Thomas H. MacDonald, Chief of the Bureau of Public Roads, holds that if these bonding companies were to make a more careful study of their risks before issuing bonds, great advantage might be derived. At the coming meeting, the advisability of a secondary or new and less expensive type of road will also be discussed. This road to be used on less frequented highways of secondary traffic.

The secondary and local roads of this country have a far greater mileage than the main traffic lines, yet relative to very large mileage, little progress has been made along the lines of improving this type of construction. Because of the small amount of traffic on the local roads, surfaces such as concrete, asphalt and brick are not possible because of the great cost of building the hard surfaced types.

Presentation of 27th Regiment Colors

The colors of the 27th Engineers were turned over to the United Engineering Society by the State of New York at a ceremony in the Engineering Societies' building, 29 West 39th St., Friday evening, November 14th. After a few introductory remarks by Walter R. Ingalls, an address was made by Col. O. B. Perry, commander of the regiment during its service in France, in which he gave interesting details of the organization of the regiment and its unusual achievement in the American Expeditionary Forces. The colors were formally accepted by W. D. L. Saunders of the United Engineering Society and chairman of the Naval Consulting Board, and Col. Ladue, engineering officer of the Second Corps Area, representing General Bullard, spoke on preparedness from an engineering standpoint. Others present at the meeting were members of the Advisory Committee of the Association of the 27th Engineers, presidents and secretaries of the four Founder Societies, trustees of the United Engineering Society and officers of the United States Army.

100 Per Cent Become Enrolled Students at Moore School of E. E.

Every senior and junior student of the Moore School of Electrical Engineering, University of Pennsylvania, has enrolled as a Student member of the American Institute of Electrical Engineers. Altogether thirty-five students have so enrolled.

This is a record of which the school can be proud and for which much credit should be given to those who have worked for the progress of the Student Branch, notably to Walter J. Seeley, Chairman of the Branch, and Charles L. Apker, who has charge of the membership committee.

Annual Meeting of The American Society of Mechanical Engineers

The American Society of Mechanical Engineers is holding its forty-fifth Annual Convention at the Engineering Societies Building, 29 West 39th Street, Dec. 1-4. A most interesting and instructive program has been planned for these four days, and a thoroughly enjoyable and helpful series of meetings is anticipated.

Nomination and Election of Institute Officers for 1925-1926

As provided in Section 19 of the Institute By-Laws, candidates may now be proposed for nomination for the offices to be filled at the next annual election in May, 1925, by the petition or by the separate endorsement in writing, of not less than twenty-five members. The petitions or separate endorsements must be in the hands of the Secretary not later than January 25, 1925. For the convenience of members, a form of petition has been prepared by the Secretary, and copies of it may be obtained upon application to Institute headquarters. Endorsements may, however, be made by letter if the form is not available. A member is not limited in the number of candidates he may endorse in this manner.

The officers to be elected are: A President and a Treasurer for the term of one year each, five Vice-Presidents for the term of two years each (one from each of the even numbered geographical districts), and three Managers for the term of four years each.

The five even numbered districts from which Vice-Presidents are to be chosen at the May 1925 election are as follows:

2. Middle Eastern: Delaware, District of Columbia, Maryland, New Jersey (exclusive of N. Y. Section territory), Ohio, Pennsylvania, West Virginia.

4. Southern: Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia.

6. North Central: Colorado, Iowa, Minnesota, Nebraska, North Dakota, South Dakota, Wyoming.

8. Pacific: Arizona, California, Nevada, Hawaii, Phillippines.

10. Canada.

According to the revised Constitution while one Vice-President must be elected from each of the five even numbered districts, this does not debar members in one district, if they so wish, from nominating and voting for a candidate in another district. When the votes are counted the candidate for Vice-President having the largest vote in each district will be elected to that particular office for that district, irrespective of the fact that he may have polled a smaller number of votes than a candidate standing second in another district.

For the information of members the full text of revised sections of the Constitution and By-Laws applying to Officers, nominations, elections, etc., are printed below:

CONSTITUTION

Sec. 23. The officers of the Institute shall be a President, one Vice-President from each geographical district as defined in the By-Laws, twleve Managers, a Secretary and a Treasurer.

Sec. 24. The President, the Secretary and the Treasurer shall hold office for one year, the Vice-Presidents for two years and the Managers for four years. The President and Managers shall not be eligible for immediate re-election to the same office. No Vice-President or Manager who has served continuously in one or more offices, and whose combined terms shall have aggregated six years or more shall be eligible for immediate election to the office of Manager or Vice-President. At each Annual Meeting the President, the requisite number of Vice-Presidents to fill vacancies caused by expiration of terms, three Managers and the Treasurer shall be elected by the membership, and their terms of office shall commence on the first of August next succeeding their election...............

Sec. 24A. At the election of Vice-Presidents held in 1921 there shall be elected one Vice-President from each geographical district, those from the odd-numbered districts to serve for one year each, and those from the even-numbered districts two years each. All Vice-Presidents elected thereafter shall serve for two years each. In the event of a change in the geographical districts, the Vice-Presidents then in office shall complete their terms. In case of revisions of the geographical districts, the Board of Directors shall have the power to elect a Vice-President from each district not represented to serve until the next election covering these districts.

BY-LAWS

Sec. 19. In addition to the names of the incumbents of office the Secretary shall publish on the form showing offices to be filled at the ensuing annual election in May provided for in Article VI, of the Constitution, the names, as candidates for nomination, of such members of the Institute as have been proposed for nomination for a particular office by the petition or by the separate endorsement of not less than twenty-five members, received by the Secretary of the Institute in writing by January twenty-fifth of each year; provided, however, that any candidate proposed for nomination by petition may withdraw his name by written communication to the Secretary, and any name so withdrawn prior to the printing of the form shall not be published.

The names of such candidates for nomination shall be grouped alphabetically under the name of the office for which each is proposed, and this by-law shall be reprinted prominently in the December and January issue of each year's Journal and shall be reproduced on the form above referred to.

Sec. 21. There shall be ten geographical districts grouped as follows: (For the balance of this Section describing districts see By-laws and map.)

Sec. 21A. Should the territory of any Institute Section lie in more than one geographical district as defined above, then the entire territory of said Section shall be considered as belonging to the geographical district in which the headquarters of the Section are located.

American Association for the Advancement of Science

The American Association for the Advancement of Science aims to promote the advance of all branches of scientific work. It has a section devoted to Engineering Science, with which the following engineering societies are affiliated, each of them having representation in the Council of the A. A. A. S. and in the section committee: The American Society of Mechanical Engineers, The American Institute of Electrical Engineers, The American Institute of Mining and Metallurgical Engineers, The American Society of Civil Engineers, The Illuminating Engineering Society, and The American Society for Testing Materials. Many of the other sections of the Association, of which there are now fifteen, represent scientific fields in which engineers are vitally interested.

The officers of the A. A. A. S. have extended an invitation to the members of any of the affiliated societies mentioned above to join the Association prior to January first 1925 without paying the usual entrance fee. The annual dues are five dollars, and each member is entitled to receive either the weekly journal *Science* or the *Scientific Monthly*.

A booklet of information regarding the organization and activities of the Association and a sample copy of either or both of the above-named publications, will be sent upon request addressed to Dr. Burton E. Livingston, Permanent Secretary, Smithsonian Institution Building, Washington, D. C.

ENGINEERING FOUNDATION

U. S. SCIENTISTS TO HONOR CARNOT

A celebration in honor of "the centenary of the announcement in 1824 by Nicholas Leonard Sadi Carnot of the second law of thermodynamics and the Carnot Cycle" will be held on December 4, in the Engineering Societies Building, New York City, under the auspices of the Engineering Foundation. Leaders in the world science will take part in the program, which promises to be of the greatest interest. Prof. William F. Durand of Leland Stanford University and president of the A. S. M. E., will preside. Dr. William LeRoy Emmet, consulting engineer of the General Electric Company, and Dr. Michael I. Pupin, professor of electromechanics in Columbia University, will deliver addresses.

Representatives of the French Ministry of Public Instruction and of French societies will attend. A message will be read from L'Ecole Polytechnique, where Carnot studied.

Cooperating with the Foundation are Columbia University, New York University, Stevens Institute of Technology, College of the City of New York, Polytechnic Institute of Brooklyn, Pratt Institute, and Cooper Union.

Also taking part, in addition to the Four Founder Engineering Societies, are the American Physical Society and the American Chemical Society.

NEW NATIONAL PERSONNEL INVESTIGATION BUREAU

At a recent meeting of the Engineering Foundation, Dr. W. V. Bingham, of the Carnegie Institute of Technology of Pittsburgh, was appointed chairman of a national investigation bureau which will be headed by the Personnel Research Federation, with headquarters at the offices of the Foundation, 29 West 39th Street, New York. The ambition of this new bureau of research, as Mr. Flinn emphasized in his remarks, will be the amalgamation of all industrial, educational and commercial interests in a common development for the general good of humanity. Thus it is expected to make it include the collaboration of such interests as the National Research Council, Engineering Foundation, representative vocational and educational factors, physicians, physiologists, psychiatrists, psychologists, university departments active in commercial and administrative training, as well as government departments of Labor, Hygiene, Bureau of Mines and Civil Service commissions.

PERSONAL MENTION

Arthur A. Van Pelt is now engaged as Chief of Engineering-Automotive Depts. of the Colonial Supply Co., Pittsburgh, Pa.

Edgar H. Felix, Radio Broadcasting Press Representative for the American Tel. & Tel. Co., 195 Broadway, should be addressed at 2305 Sedgwick Avenue, New York City.

Harold M. Hould has risen from his previous position of electrical engineer for the Dept of Street Railways, Detroit, Michigan, to the office of Assistant General Manager.

Fred Elton Chapman, former Assistant Engineer of the Bangor Railway & Electric Co., has recently been made Assistant Engineer of the Carolina Power & Light Co., Raleigh, N. C.

P. D. Chang, formerly associated with the General Electric Co. and the Foos Gas Company in China, has now accepted a position as Chief Engineer of the Soochow Electric Light & Power Co., Soochow, China.

John A. Grant, has left the State Electricity Commission of Victoria, Testing Dept., and has become Electrical Draftsman for the Commonwealth of Australia, Dept. of Works and Railways, Melbourne, Victoria.

Walter Roland Roxbury, who for some time past has been Valuation Engineer for The Barrett Company, 40 Rector St., New York City, is now serving The Murrie Company, Everett Building, this City, in like capacity.

G. E. Orley has resigned his position as Assistant Electrical Engineer of the N. Y.-N. J. Bridges and Tunnel Commissions, to take a position as Electrical Designing Engineer with the Public Service Production Co. of New Jersey.

Harry F. Franklin, who was Superintendent of Construction for the Electric Bond & Share Co. of New York in Ciego de Avila, Cuba, has been transferred to their New York office as Superintendent of Construction and Maintenance.

James C. Merritt announces that he has severed his connection with the Shawinigan Water & Power Company and is now District Representative for the Dominion Insulator & Mfg. Company, Limited, 416 Phillips Place, Montreal, Canada.

E. Gray-Donald has resigned from his position as draftsman in the Distribution Dept. of the Toronto Hydro-Electric System, with whom he has been for the past eighteen months, in order to continue his course at McGill University, Montreal.

Roger T. Smith, formerly with the Great Western Railway, 66 Porchester Road, Paddington, W. 2 London, has formed a partnership in consulting engineering with Messrs. J. S. and W. E. Highfield, 36 Victoria Street, London, S. W. 1, England.

Edward S. Ford, who has been Electrical Tester for the Westinghouse Elec. & Mfg. Co., at East Pittsburgh, has been appointed Cleveland representative for the Star Electric Motor Co., with offices in the Rockefellow Building, Cleveland, Ohio.

Karl J. Larsson, formerly affiliated with the St. Cloud Electric Machinery Company, St. Cloud, Minn., has accepted a position as Instructor of Electrical Instrument and Meter Technic at the State School of Science, Wahpeton, North Dakota.

J. M. Gillham, previously of Kansas City, Mo., has been appointed Supt. of the Underground Portland Electric Power Co., Electric Building, Portland, Oregon. Mr. Gillham's work in Kansas City was with the Kansas City Power and Light Company, as Supt. of Underground Cable Engineering.

Benjamin Midulla of R. Polytechnic of Turin, Italy, has left the employ of the N. Y. Edison Co. and, as a winner of the Fellowship given by the Italy-America Society, is now attending for the third year the School of Electrical Engineering at Columbia University, preparatory to obtaining the American degree.

Maurice N. Blakemore, former Vice-President of Moody's Investors Service, announces, the opening of his own office as Financial Counselor and Analyst. This will include the giving of personal advice on investment problems, general commercial investigations, reports and appraisals of concerns already operating, as well as prospective ones.

F. M. Bond informs us that he has been appointed Industrial Commissioner, Norfolk-Portsmouth Chamber of Commerce, Bank of Commerce Bldg., Norfolk, Va. Here Mr. Bond will organize a Bureau to be engaged in furnishing industrial surveys and special reports on economic conditions and cost of doing business with Norfolk and Portsmouth industries.

N. S. Diamant, who for some time has been Consulting Engineer for the Hupp Motor Car Corp. and the Jamestown Car Parts Mfg. Co., with headquarters at Jamestown, N. Y., has now removed to Detroit, where the Hupp Motor Car Co. and the National Radiator & Mfg. Corp. have established new headquarters. He is still with them as Consulting Engineer.

G. E. Emmons, Vice President in charge of manufacturing of the General Electric Co. has asked to be relieved of his duties with the company and plans to move from Schenectady to Pasadena, Cal. Mr. Emmons has been identified with the company since 1886 actively engaged during thirty years of that period in the management and development of the manufacturing department of the General Electric.

J. Oscar Amstuz has just made new business connections as Electrical Engineer of El. Railroad Solure-Berne, Soleure, Switzerland. This is a change from the superintendency of the Maximo Radio Mfg. Co., Aarau, Switzerland, with whom Mr. Amstuz has been identified for some time past. It is of further interest to know that Mr. Amstuz is now in charge of building the new electric line Zollikofen-Berne.

Obituary

Henry J. Crowley, Fellow in the American Institute of Electrical Engineers, died at his home, 4339 Pine Street, Philadelphia, Monday, October 27th, after a long illness. He was born at Unionville, Conn., and upon graduation from High School, served an apprenticeship in mechanical engineering with the Pratt & Whitney Co., Hartford, Conn. His first work thereafter was in the shops of the New York, New Haven & Hartford Railroad, at Hartford. In 1882 the Schuyler Electric Light Company organized, locating at Hartford, and Mr. Crowley joined them, passing through their various departments and while with them, assisting in many important installations made both in New England and in Pennsylvania west of Pittsburgh. So rapid was his progress that in 1889, one year after entering their employ, he was made chief of the company's experts, taking charge of their Students' Course at Lynn, Mass. In 1890 he was given the managership of the company's southern offices at Atlanta, Ga., where he remained until 1893, having charge of railway installations in Atlanta, Macon, Augusta, Savannah, Birmingham, Mobile, Chattanooga and Memphis. From 1893 to 1899 he was engineer and manager for the General Electric Company, in charge of their Railway Department for the Eastern District including Southern New Jersey, Pennsylvania, Eastern Ohio, Delaware, Maryland and North Carolina, while there accomplishing many important installations in Philadelphia, Harrisburg, Washington and Richmond. When the American Railways Company, (now the American Electric Power Company) organized in 1899, Mr. Crowley became their general manager, which position he occupied until the time of his death. During the Spanish-American War, he organized a volunteer electrical corps and had charge of the placing of submarine mines, searchlights, and telephone and telegraph systems at Fort Delaware opposite New Castle. Mr. Crowley was also Fellow in The American Society of Mechanical Engineers and member of the Art Club and Electric Club of Philadelphia.

Robert W. Thompson, Associate of the Institute, died October 4th at Seattle, Washington, where he had been Secretary of the electrical engineering firm of Thompson & Castleton, Inc. since 1918.

Earle Hager Shive of Collingdale, Pa. and recently elected to Associate membership, died October 13th. Mr. Shive began as an electrical cleaner in an emergency generating station, but in eight years had achieved the position of Assistant Load Dispatcher with the Philadelphia Electric Company, in which capacity he was serving at the time of his death.

Eugene Frank, Associate Member of the A. I. E. E., died at his home on November 13th, 1924. After public school, Mr. Frank was for two years in the Lenox Institute, immediately thereafter entering the Stevens Preparatory School. In 1895 he entered the drafting department of the Garvin Machine Co., remaining with them a year. He next became superintendent of the E. G. Bernard Co., but left them in 1900 to attend the School of Applied Science, Columbia University. Here he earned his M. E. degree and thereafter practised as electrical and mechanical engineer, in co-partnership with Herbert S. Hanan, under the firm name of Frank & Hanan, New York City.

Charles Proteus Steinmetz, a Biography

One of the most interesting biographies which have been written in recent years is the one by John W. Hammond entitled "Charles Proteus Steinmetz." From the beginning of this great engineer's career in Germany, through the time of his coming to America and struggling toward the great achievements which he finally accomplished, to his last peaceful hours in Schenectady, this book abounds in intimate personal events surrounding his life. It is a biography which anyone would be interested in. The "Great Steinmetz" possessed the keenest sense of humor, the kindest heart and that most valuable asset—the ambition to go ahead and overcome all obstacles. Anyone who reads this book will not find a technical account of his career as an electrician, but a most human and interesting portrait of his personal and professional activities.

American Engineering Standards Committee

GROWTH OF STANDARDIZATION ABROAD

All the important industrial countries of the world are making great strides in the development of their products through standardization. National organizations in various countries have been formed and already remarkable savings have been effected through their work. Switzerland, Norway, Poland, France, Japan, Holland, Italy, Germany, Austria-Hungary, Sweden, and Czechoslovakia have in the past few years made great progress along these lines.

The British Engineering Standards Association, the oldest and largest of the national standardizing bodies, has recently completed the tabulation of dimensions and properties of standard rolled steel sections for structural purposes. Both the German and British organizations have discussed the coding of standardized items.

The Canadian Engineering Standards Association endeavors to cooperate with both British and American standards and one of their most important projects is a "Canadian Electrical Code" which is based largely upon the American standard electrical codes for protection against fire and casualty hazards. Much interesting data are also available on oil and gasoline for automotive purposes.

PAN AMERICAN CONFERENCE ON STANDARDIZATION

The twenty-one Republics in the Pan American Union have been invited by the Peruvian Government to attend a Conference on Standardization at Lima, Peru beginning December 23rd, 1924.

A large number of technical and trade organizations from many countries has been asked to send representatives.

The purpose of this Conference is to study the possibilities of developing inter-American and international standards for raw and finished materials, as well as standardized classifications and nomenclature, and to make recommendations in regard to their development.

The Peruvian Government has the co-operation of the Pan American Union, the Inter-American High Commission, the United States Departments of Commerce and Agriculture and the American Engineering Standards Committee.

Any organization desiring an invitation for a delegate to this Conference should communicate with the American Engineering Standards Committee.

New Book of A. S. T. M. Tentative Standards

The American Society for Testing Materials announces the publication of their new Book of A. S. T. M. Tentative Standards, containing 763 pages and descriptive of 185 Tentative Standards. The publication of these Tentative Standards is to elicit criticism from sources of authority before their final adoption as accepted working Standards.

Personnel Research Federation

The Personnel Research Federation was established in 1921, under the auspices of Engineering Foundation and National Research Council. It comprises more than twenty societies, research bureaus and universities engaged in the scientific investigation of problems affecting workers and their work.

The activities of this Federation that interlock most closely with the interests of the Engineering Societies include, 1. the study of placement agencies and their efficient functioning in bringing men and jobs together; 2. the collection of information about opportunities and careers as an aid not only in placement but also in educational guidance, in high-school, engineering-school and college; and 3. the investigation of effective methods and practices of industrial personnel administration.

The official publication of the Federation is the *Journal of Personnel Research*, which has recently contained contributions by engineers on such topics as Engineering Aptitudes, Motion Studies, Industrial Accident Prevention, and Tests of Railroad Personnel, as well as articles by physicians, psychologists, economists and labor leaders on technical aspects of personnel matters. The cooperation of such a varied group of specialists is an outstanding feature of this organization established to promote research activities pertaining to personnel in industry, commerce, education and government, wherever such researches are conducted, not in a partisan spirit or for propaganda, but in the spirit and in the methods of science.

The member organizations are widely distributed, in Philadelphia and Washington, Pittsburgh and Chicago, North Carolina, New Hampshire, Michigan and Massachusetts.

Member organizations include the National Research Council, Engineering Foundation, American Federation of Labor, Bureau of Vocational Information, Vocational Service for Juniors, Department of Industrial Research at the University of Pennsylvania, the Graduate School of Business and the Bureau of Vocational Guidance at Harvard University, National Committee for Mental Hygiene, U. S. Public Health Service, U. S. Bureau of Labor Statistics, U. S. Bureau of Mines, U. S. Civil Service Commission, Research Bureau for Retail Training at the University of Pittsburgh, School of Business Administration at the University of Chicago, and departments active in personnel research at Dartmouth College, Bryn Mawr College, Northwestern University, University of North Carolina and the University of Michigan. The membership includes also individuals and industrial corporations.

W. V. Bingham, of Carnegie Institute of Technology, has been appointed Director of Personnel Research Federation which has its office in the Engineering Societies Building, 29 West 39th Street, New York City. The new Director comes to New York from Pittsburgh, where for nine years he was Professor of Psychology at Carnegie Institute of Technology. In the National Research Council he was the first Chairman of the Division of Anthropology and Psychology.

The plans of the Personnel Research Federation for the coming year, as formulated by its Board of Governors, include certain studies to be carried forward by the central staff. Major investigations, as heretofore, will be made under the direct supervision of member organizations. The energies of the Director and his assistants will be concentrated on the establishment of a clearing house for information about problems, researches in progress, sources of data, and methods of investigation. Existing research facilities and the most promising lines of inquiry will be inventoried to determine opportunities for progress. Much is to be accomplished through the discovery and collection of unpublished reports and notes of research on industrial fatigue and industrial hygiene, including mental hygiene; hiring, placing and training of workers; methods of wage payment; non-financial incentives and rewards; vacations with pay; personnel records and forms; methods of personnel administration, vocational guidance and placement in colleges and schools; selection and development of executives, and other live topics of personnel research on which data are often buried in the files of business concerns, trade associations, labor organizations, government bureaus and university departments. To find these materials and make them accessible through the columns of its *Journal of Personnel Research* is but one of the important ways in which Personnel Research Federation will meet its opportunity for useful service to education, commerce and industry.

Assistance will be available for member organizations, manufacturers' associations, labor groups and university departments wishing to be brought into touch with authorities on the several aspects of their personnel problems. Joint effort of many co-workers will speed the clear definition of puzzling questions about workers in relation to their jobs and opportunities, and point the way toward the solution of these questions by scientific, impartial, disinterested methods.

"The right man in the right place," implies study not only of the abilities, training and economic needs of men and women, but also of conditions of work, incentives, rewards, and opportunities for growth and advancement. To encourage and co-ordinate investigations bearing on these vitally important subjects is the function of Personnel Research Federation.

Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute Headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—C. E. Buchan, 1276 Eustis St., St. Paul, Minn.
2.—Harry S. Buchanan, 134 E. Ave. 54, Los Angeles, Calif.
3.—Ed. J. Ensweiler, 865 25th St., Milwaukee, Wis.
4.—Jacob G. Feldman, Allied Electric Co., Inc., Suite 3519, Grand Central Sta., New York, N. Y.
5.—C. H. Gauss, 2319 E. Fayette St., Baltimore, Md.
6.—Frank Goldenberg, 2821 Windsor Ave., Baltimore, Md.
7.—Richard J. Grant, 107 E. South St., Pontiac, Ill.
8.—Frank W. Gross, 1135 W. 5th St., Santa Ana, Calif.
9.—T. J. Hodge, Engineering Dept., Memphis Pr. & Lt. Co., Memphis, Tenn.
10.—George Janssen, The Roxana Petroleum Corp., Arkansas City, Kans.
11.—W. W. Johnson, 320 So. 19th Ave., East, Duluth, Minn.
12.—J. M. Kingsbury, 331 West 83rd St., New York, N. Y.
13.—George J. Lechner, The Edward-Johns Co., 1740 East Twelfth St., Cleveland, Ohio
14.—E. R. McNee, 18 So. Seeley Ave., Chicago, Ill.
15.—F. M. Meyerend, New York Edison Co., 555 Tremont Ave., Bronx, New York, N. Y.
16.—James D. Newman, Dallas Pr. & Lt. Co., 1410 Jackson St., Dallas, Tex.
17.—J. C. Peterson, 323 W. Navarre St., South Bend, Ind.
18.—Geo. W. Powell, Erection Dept., Allis Chalmers Mfg. Co., Milwaukee, Wis.
19.—Thomas F. Slattery, St. George Court, Stuyvesant & Wall St., St. George, Staten Island, N. Y.
20.—Max E. Sporn, 242 Penn St., Brooklyn, N. Y.
21.—John H. Spring, 5 York St., St. Catharines, Ont., Can.
22.—Foster Strong, 57 South 7th East St., Salt Lake City, Utah.
23.—J. L. Twining, Apt. 32, 703 9th Ave., Seattle, Wash.
24.—A. W. West, Bibb Mfg. Co., Porterdale, Ga.
25.—Thomas Whitmore, 1803 W. Pacific Ave., Spokane, Wash.

Plans for 1925 Edition National Electrical Code

There will be a 1925 edition of the National Electrical Code, the Rules and Regulations for Electric Wiring and Apparatus. This was determined at a meeting of the reorganized Sectional Electrical Committee of the National Fire Protection Association, held in New York City on Friday, November 21, 1924.

Inspection and regulatory bodies, manufacturers, utilities, property owners, users or others who have proposals for additions or other amendments to the National Electrical Code, edition of 1923, can be assured of full consideration if these proposals are submitted in writing to the Chairman of the Committee, A. R. Small, 109 Leonard Street, New York, N. Y., not later than December 15, 1924. Such proposals should preferably refer to a particular article and paragraph of the 1923 edition, and shall in all cases be readily identifiable as to the name, address and interest of their submittors.

A New Training Course for Illuminating Engineers

A practical training course in lighting, under the joint auspices of the Illuminating Engineering Society and the Lighting Bureau of the National Electric Light Association, has been established, and, as a result, sixteen men were recently registered with twelve actually completing the course. A most enjoyable instruction and inspection tour was held October 6-26, through places of interest in some of the principal cities,—Chicago, South Bend, Ind., Detroit, Cleveland, Washington and New York,—by which the students were afforded opportunity for personal observation of the essential points in this field. The necessity of such a

course was the outcome of discussion of the Lighting Bureau in 1922, leading to the appointment of a special committee by the chairman of the N. E. L. A. Commercial Section. In 1923-4 arrangements were effected with the Illumination Engineering Society to undertake the conduct of this training course.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES (OCT. 1-31, 1924)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

Bookkeeping and Introductory Accounting.

By Henry W. Sweeney. Ed. 1. N. Y., McGraw-Hill Book Co., 1924. Forms (Commercial Education Series). 9 x 6 in., cloth.

A textbook which aims to present the subject so clearly and simply that any intelligent person can understand it without outside aid and prepare himself for actual bookkeeping and accounting work in the business world. It will also prove useful to those who wish a knowledge of the subject but are not interested in becoming bookkeepers.

Eisenhuttenkunde, Teil I, Das Roheisen.

By M. von Schwarz. Berlin, de Gruyter, 1924. 128 pp., illus., tables, diagrs., 6 x 4 in., cloth, 1.25 g. m.

A remarkable condensed description of the metallurgy of pig-iron. Opening with a historical and economic survey of the iron industry, the author rapidly considers the properties of the various commercial grades of iron, iron ores, fluxes and slags, blast-furnace fuels, the blast-furnace process, mixers, electric and direct processes, cupolas and air furnaces, and welding processes. A list of important books is included.

Die Elektrische Messtechnik, Teil I, Die elektrischen Messmethoden im Allgemeinen.

By J. Herrmann. Berlin, De Gruyter, 1924, illus., diagrs. (Sammlung Goschen). 4 x 6 in., cloth. 1.25 g. m.

The present volume is the first of three on electric measurements, intended to give a brief practical survey of the field. It presents the basic principles of the subject in the simplest form possible, giving descriptions of the methods, with schematic drawings and wiring diagrams.

Industrial Electricity, Pt. 1.

By Chester L. Dawes. Ed. 1. N. Y., McGraw-Hill Book Co., 1924. 14 + 371 pp., illus., diagrs., 8 x 5 in., cloth. $2.25.

A textbook for use in technical high schools and other schools not of collegiate grade where courses in elementary electrical engineering are offered. It explains in simple language the principles that underly electrical apparatus and gives a bird's-eye view of electrical engineering and its problems, adapted to beginners in these schools or to private students.

Die Lokomotive in Kunst, Urtz und Karikatur, Hannoversche maschinenbauactien-gesellschaft. Hanover-Linden, Hanomag-nachrichten Verlag, 1922, illus., 9 x 11 in., paper. $.50.

To celebrate the completion of its ten-thousandth locomotive, the Hanover Machine Company has issued this work, which will undoubtedly prove of interest to all railroad men, and to engineers generally. From a wide range, illustrations and caricatures, poems, historical articles, jokes, etc., have been assembled and published in a handsome volume at a nominal price. The full-page colored illustrations are excellent.

Management's Handbook.

By L. P. Alford, Editor-in-Chief. N. Y., Ronald Press Co., 1924. 1607 pp., illus., charts, tables, 7 x 5 in., fabrikoid. $7.50.

The development of the art of management during the past twenty-five years has resulted in the accumulation of a body of fundamental principles, systems and methods which have been approved and adopted generally. This handbook is intended to provide a systematic summary of the best information available in the management of manufacturing industries, in a convenient form for reference.

The matter presented falls in three groups. The first contains general information upon such topics as tables, statistics, charts, graphs, management ratios and mathematics. Section two deals with the functions, methods and mechanisms of management. The third section contains basic information on the economic principles that underly industry.

Each section is sponsored by a specialist. The book is intended for managers, executives and engineers.

Protection of Steam Turbine Disk Wheels from Axial Vibration.

By Wilfred Campbell. Schenectady, General Electric Co., 1924, illus., diagrs., 8 x 10 in., cloth. $1.00.

This work describes the main features of an extensive investigation of the various forms of vibration and waves which may exist in turbine disk wheels, carried out by the General Electric Company. The investigation resulted in the determinations of methods for designing and testing which insure freedom from axial vibration.

The book was presented as a paper before the American Society of Mechanical Engineers in 1924.

Railway Transportation, Principles and Point of View.

By Sidney L. Miller. Chicago, A. W. Shaw Co., 1924, maps, tables, diagrs., 6 x 8 in., cloth. $4.00.

A discussion of the railroad "problem" from the point of view of the public, written for those who wish a better understanding of it, as a basis for its solution.

After a discussion of the relation of transportation costs to social and trade development, the author sets forth the growth of our railroad system and shows the existing grouping of railroads by ownership as well as by territory. The economics of operation and the problems pressing for solution are discussed. The author takes up the conception of the railroad as a competitive enterprise, points out the growth of co-operation, analyzes capitalization and explains the different bases for determining the true worth of railroads. The question of rate-making is presented, and consideration is given to government regulation.

Wireless Possibilities.

By A. M. Low. N. Y., E. P. Dutton & Company [1924] diagrs., 6 x 5 in., cloth. $1.00.

Calls attention to some of the things that wireless can not do today but which may become possible hereafter.

Past Section and Branch Meetings

SECTION MEETINGS

Akron

Some Fundamental Properties of Electrons, by Professor Vladimir Karapetoff. The lecture dealt chiefly with the work of Millikan in measuring the charge, mass and velocity of single electrons. The speaker also furnished a splendid piano recital. October 17. Attendance 200.

Atlanta

Mr. H. M. Keys, Commercial Survey Engineer of the Southern Bell Telephone & Telegraph Co., gave a very interesting and instructive talk on the commercial survey of large cities, with particular reference to the City of Atlanta and the State of Georgia. November 3. Attendance 44.

Boston

Mr. I. E. Moultrop outlined the mechanical features of the Weymouth Station of the Edison Electric Illuminating Company of Boston. Mr. M. J. Lowenberg outlined by slides the electrical features of the plant. After the talks the station was inspected. October 18. Attendance 250.

Chicago

High-Tension Phenomena, by Dr. G. Faccioli. Joint with Western Society of Engineers. October 6. Attendance 470.

Cleveland

Synchronous Motor Applications, by James Burke, President, Burke Electric Company of Erie, Pa. After discussion of the paper a motion picture, entitled "The Heart of Cleveland," was shown. Mr. C. P. Cooper, local Section Chairman, spoke briefly of the plans for the coming year. October 11. Attendance 136.

Connecticut

What the First World Power Conference Accomplished, by H. V. Bozell, Editor of the *Electrical World*. The speaker summarized the whole attitude of the Conference in two queries: "What is America doing?" and "How does America do it?" October 14. Attendance 35.

Denver

Lightning, by F. W. Peek, Jr., General Electric Co. The speaker explained its effect on transmission lines, as determined from tests made on actual high-tension circuits, and also by the use of the 2,000,000-volt generator in the laboratories. The talk was illustrated by motion pictures and slides. October 28. Attendance 70.

The regular luncheon of the Colorado Engineering Council was held under the auspices of the Denver Section A. I. E. E. Mr. Harry Satenwater outlined the construction and operation program of the General Electric Radio Broadcasting Station No. 3 in Denver. October 28. Attendance 50.

Detroit-Ann Arbor

The Power Development at Niagara Falls, by John L. Harper, Vice-President and Chief Engineer, Niagara Falls Power Co. The talk was illustrated with slides, showing the first stations utilizing the power of the Falls and the tunnel built under the City of Niagara Falls. October 21. Attendance 175.

Erie

Dreams and Visions, by Dr. Harry B. Boyd. A buffet luncheon was served. October 21. Attendance 70.

Fort Wayne

Your City, by C. B. Fitch. Luncheon was served. October 30. Attendance 32.

Indianapolis-Lafayette

Evolution of the Synchronous Machine from the Early Days to the Present Time, by Theodor Schou, Chief Engineer, Ideal Electric and Manufacturing Co. The talk was illustrated with slides. September 26. Attendance 32.

Radio, by Professor R. V. Achatz, Purdue University. October 31. Attendance 20.

Ithaca

Social Meeting. October 24. Attendance 115.

Kansas City

Some Problems in Power Transmission, by R. E. Doherty, General Electric Co. Music was furnished and a buffet luncheon was served. November 5. Attendance 60.

Lehigh Valley

Super-Power, Mr. H. G. Harvey, Manager, Pennsylvania Edison Co., showed three reels of pictures, and

The Transformer in Super-Power Distribution, by H. O. Stephens, General Electric Co. October 23. Attendance 53.

Madison

An Experimental Rural Power Line, by Professor F. W. Duffee, University of Wisconsin. October 31. Attendance 40.

Minnesota

Home Lighting, by Professor George D. Shepardson, University of Minnesota. The talk was illustrated with lantern slides. October 27. Attendance 55.

New York

Radio Broadcasting. The first speaker, E. W. Harkness, Assistant Vice-President, American Telephone and Telegraph Co., spoke on "Operating a Broadcasting Station," discussing operating organization, program material, gauging reaction of the radio audience, etc. The second speaker, A. Stein, Jr., Managing Engineer, Radio Dept., General Electric Co., gave "A Comparison of American and European Broadcasting Systems." He compared the systems of England, France and Germany with the American, covering governmental, financial and technical relations, publicity and future. Directly preceding the meeting an informal dinner was held at the Cafe Boulevarde. This innovation bore out the belief of the Executive Committee of the Section that members would welcome an opportunity of informally gathering and having supper together and of meeting friends and associates in the electrical field. Joint meeting with the New York Electrical Society. November 12. Attendance 450.

Philadelphia

Recent Developments in Radio Engineering, J. H. Dellinger, Bureau of Standards. October 13. Attendance 200.

Pittsburgh

Artificial Light and Civilization, by M. Luckiesh, National Lamp Works of General Electric Co. October 14. Attendance 145.

Pittsfield

Transient Phenomena, by G. Faccioli. The speaker pointed out that with the higher voltages used in more recent electrical transmission, a careful study of the occurrences due to switching, short-circuits and lightning is necessary. The lecture was illustrated with slides. Music was furnished and refreshments were served. November 4. Attendance 425.

Portland

World Power Conference at London, by C. P. Osborne, Portland Electric Power Co., and

A. I. E. E. Annual Convention at Chicago, by F. H. Murphy, Portland Electric Power Co. September 24. Attendance 70.

Institute Affairs, by President Farley Osgood. Joint with N. E. L. A. A dinner preceded the meeting. October 23. Attendance 85.

St. Louis

The Power Plant and Substations of the Union Electric Light & Power Company, by W. H. Millan, and

The Transmission and Distribution System of the Union Electric Light & Power Company, by Chris H. Kraft, and

Home Engineering and Economic Features of the Union Electric Light & Power Company's Systems, by E. Ettlinger. Entertainment was furnished and refreshments were served. September 24. Attendance 125.

The World Power Conference, by Louis H. Egan, President, Union Electric Light & Power Co. Joint meeting with the Associated Engineering Societies of St. Louis. October 28. Attendance 150.

San Francisco

Power Development and the World Power Conference, by C. E. Skinner. September 26. Attendance 85.

Schenectady

Social Meeting. Short talks were given by Messrs. R. C. Muir, L. T. Robinson and John W. Taylor. October 10. Attendance 465.

Southern Virginia

The Equipment and Operation of the Virginia Railway Coal Pier No. 2 Sewalls Point, by F. F. Harrington, Chief Engineer, Virginia Terminal Railway.

Material-Handling Industrial Trucks, by Louis W. Sipley, Alfred J. Forschner Co. October 17. Attendance 80.

Spokane

President Farley Osgood gave an address on Institute affairs in general. A short talk was also given by Mr. E. H. Hubert, Secretary of the National Meetings and Papers Committee. October 29. Attendance 30.

Springfield

Illuminated Traffic Signals, by J. G. Regan, General Electric Co. October 6. Attendance 61.

Railway Electrification, by N. W. Storer, Westinghouse Electric & Manufacturing Co. October 27. Attendance 92.

Toledo

Inspection trip through the plant of the Owen's Bottle Co. October 22. Attendance 40.

Toronto

My First Connections with Public Electricity Supply, by Dr. S. Z. De Ferranti, President, Ferranti Limited. October 10. Attendance 146.

Joint meeting of the Engineering Societies of Toronto re "Management Week." The speakers were Professor H. Mitchell, McMaster University, and R. L. Wright, President, Canadian Society of Cost Accountants. October 23. Attendance 150.

Inspection Trip to Hydroelectric Power Commission Laboratory. The Engineer in charge of each section of the Laboratory described the work of his section. Refreshments were served. October 30. Attendance 150.

Urbana

The Design of Recording Instruments, by Chester I. Hall, General Electric Co. Especial attention was given to the recording of muscular tremors. October 29. Attendance 60.

Utah

Outing held jointly with the Rocky Mountain Electrical Cooperative League. August 19. Attendance 195.

Banquet. The delegates on the way to the Pasadena Convention of the Institute were entertained. Short talks were given by Dr. J. F. Merrill, Dr. J. B. Whitehead, and Messrs. Bussey, Yardley, Sutton, Brown, Russell, Viets, McGraw, Jr., Hubert, Amstutz, Lawson, Burnham, Kobak, Damon, Foster, and Morrow. September 30. Attendance 59.

Vancouver

Dinner Meeting. An address was made by President Farley Osgood on Institute activities and other matters pertinent to the engineering profession. A short talk was also given by Mr. E. H. Hubert, Secretary of the National Meetings and Papers Committee. October 27. Attendance 46.

Washington, D. C.

Present Day Developments in Radio Engineering, by Dr. J. H. Dellinger, Bureau of Standards. A dinner preceded the meeting and refreshments were served after the talk. October 14. Attendance 204.

World Power Conference in London, by O. C. Merrill, Federal Power Commission. November 11. Attendance 110.

Worcester

Super-Power System of the Electric Companies Affiliated with the Consolidated Gas Company of New York, by Philip Torchio, Chief Engineer, New York Edison Co. Slides and moving pictures of the generating and distribution systems of the New York Edison Company were shown. October 16. Attendance 150.

BRANCH MEETINGS

Alabama Polytechnic Institute

The Recent Improvements of the Auburn Water System and the Problems Encountered, by Dean J. J. Wilmore. October 15. Attendance 80.

The Influence of Engineers upon Our Country, by Dr. Geo. Petrie. October 29. Attendance 106.

Two General Electric Company films were presented: "The Potter's Wheel" and "An Electrical Giant." November 5. Attendance 94.

Fundamentals of Speech and Hearing, by G. B. Thomas. This lecture was illustrated with films. November 12. Attendance 140.

University of Alabama

Principles and Ideals of the A. I. E. E., by Professor Fred R. Maxwell, Jr. Short talks were also given by Charles M. Lang and L. L. Evans, students. September 30. Attendance 16.

The Story of Bakelite, by Charles M. Lang, student. This lecture was illustrated with films. A movie, entitled "A Trip to the Moon," was also shown. October 14. Attendance 20.

The Electrified Steel Rolling Mills of the Tennessee Coal and Iron Company at Fairfield or Birmingham, by Professor Kenneth McDonald. Movies were also shown. October 28. Attendance 21.

Armour Institute of Technology

Short talks were given by Mr. A. L. Stemwedel, Professor Snow and Professor Moreton. October 2. Attendance 40.

Mr. George I. Wright spoke on the electrification plan of the Illinois Central Railroad and explained the problems that had to be solved. The entire Chicago terminal improvement was explained and made very interesting by the use of slides. October 16. Attendance 52.

Mr. C. E. Tweedle, student, spoke on oil circuit breakers and their control. Mr. Arend, student, gave a talk on motor repair shop practise and Mr. Prebenson, student, explained the problems connected with the making of power cost curves for a public service company in Northern Wisconsin. October 30. Attendance 47.

University of Arkansas

Modern Power Plant Design, by Roy Fleak. Professor Cushman gave a general talk for engineers. November 5. Attendance 27.

Brooklyn Polytechnic Institute

Business Meeting. The following officers were elected: President, Wesley A. Ock; Vice-President, George F. Marks; Treasurer, Edward McCort; and Secretary, George C. Moog. November 6. Attendance 20.

Bucknell University

Electrical Engineering at Bucknell, by Professor W. K. Rhodes. Refreshments were served. November 3. Attendance 31.

California Institute of Technology

Business Meeting. Chairman William Lewis outlined the plans of the Student Branch for the coming year and presented plans for assisting in the entertainment of the delegates to the National A. I. E. E. Convention to be held in Pasadena. October 8. Attendance 26.

Voltage Regulators, by William Lewis. The speaker described and explained the operation of one form of rheostatic regulator in common use. October 22. Attendance 30.

University of California

Initiation Meeting. Refreshments were served. October 8. Attendance 66.

The Use of the Belt and Spur in Climbing, by H. F. Lusk, student.

Inductive Interference, by O. C. Cone, Pacific Telephone & Telegraph Co. October 22. Attendance 35.

Case School of Applied Science

Business Meeting. The following officers were elected: Chairman, F. B. Schramm; Vice-Chairman, L. Eisenman; Secretary, G. J. Goudreau; and Treasurer, W. H. West. October 10. Attendance 25.

University of Cincinnati

Side Lights of Electrical Engineering, by Professor A. M. Wilson. October 16. Attendance 52.

Colorado State Agricultural College

History and Advantages of the American Institute of Electrical Engineers, by Professor Jordon. The following officers were elected: President, S. Aldrich; Vice-President, Guy L. Pau; and Secretary-Treasurer, F. E. Bodine. September 15. Attendance 9.

Short talks on electrical subjects were given by two senior engineers. October 20. Attendance 18.

University of Colorado

Several talks on Summer experiences were given by faculty members. Professor W. C. DuVall spoke on the human relationships of his stay at Westinghouse; Mr. Frank Eastom spoke of some of the larger pieces of apparatus and equipment manufactured at Westinghouse; Professor M. S. Coover on his reception and treatment at Schenectady and of the things he saw and did there; Dean H. S. Evans gave an impromtu talk emphasizing the proper student attitude toward the A. I. E. E. October 8. Attendance 88.

The Lakeside Power Plant of the Public Service Company of of Colorado, by Frank Pexton, student.

The New Automatic Sub-Station, by Frank Eastom, instructor. October 29. Attendance 60.

University of Denver

Purpose and Organization of Student Branches of the A. I. E. E., by Dr. R. E. Nyswander, and

Electrification of the Moffat Tunnel, by A. H. Patten, student, and

Description of the Valmont Plant of the Public Service Company of Colorado, by C. C. Herskind, student. October 10. Attendance 18.

Drexel Institute

Business Meeting. Plans for the coming year were discussed. October 17. Attendance 20.

Iowa State College

Social Meeting. The purpose and scope of the A. I. E. E. were explained by Chairman V. L. Womeldorff and short talks were given by members of the Electrical Engineering Faculty. Music was furnished. October 2. Attendance 353.

Problems in Power Transmission, by R. E. Doherty, General Electric Company. The speaker's discussion dealt with the present day problems encountered in the transmission of large quantities of power over long distances. October 6. Attendance 145.

Kansas State College

My Summer Experience with the Utah Light and Power Company, by V. W. Nass, student, and

The Electric Drive of the U. S. S. Colorado, by Eugene Brady, student. October 13. Attendance 69.

Some Unusual Uses of Vacuum Tubes, by J. K. Swales, student, and

Oil Production and Its Development in Kansas, by A. B. Cash, student. October 27. Attendance 62.

Kansas University

A short talk was given by George Hawley, former student, on his experiences with the Doherty Interests. A film, "The Story of a Storage Battery," was shown. Music was furnished. October 9. Attendance 42.

Central Station Development and the Use of "Wired Wireless" for Communication along Transmission Lines, by R. I. Parker, General Electric Co.

Totalizing Recording Wattmeters, by L. E. Northshield, General Electric Co. October 23. Attendance 51.

Lafayette College

The Electric Shovel, by Professor King. October 11. Attendance 16.

Electrical Development as Applied to the Paper Industry, by Professor King. The talk was illustrated with slides. October 18. Attendance 9.

Marquette University

Repairing Damage Due to Sleet Storms, by Leslie Killam, Wisconsin Telephone Co. The speaker outlined the methods employed in estimating damage done to telephone lines by sleet storms and also the methods of repairing such damage. October 16. Attendance 37.

Massachusetts Institute of Technology

The "S" Tube and Gaseous Conduction, by Dr. Vannevar Bush. The talk was illustrated by experiments with two "S" tubes specially prepared by Dr. Bush. October 23. Attendance 110.

Inspection trip to the plant of the General Electric Co. November 13. Attendance 16.

Michigan Agricultural College

Improvements in Radio Equipment, by Fred Pacholke, student, and

The Merits of Different Types of Radio Equipment, by Mr. Wood, and

The Desirability of Belonging to the A. I. E. E., by Mr. Foltz, and

The Organization and Scope of the A. I. E. E., by Professor Cory.

University of Michigan

Business Meeting. October 29. Attendance 17.

School of Engineering of Milwaukee

Telephone Transmission, by W. Chunn, and

Purpose of the Student Branch, by B. A. Bovee, and

Selling Power, by L. C. Eddy. The following officers were elected: Chairman, L. C. Eddy; Vice-Chairman, E. J.

Lehnen; Secretary, E. L. Ruth; and Treasurer, A. L. Stoll. October 24. Attendance 32.

University of Minnesota

Short talks were given by Professors G. D. Shephardson, F. W. Springer and W. T. Ryan. Motion pictures on electric lighting were shown. Refreshments were served. October 29. Attendance 88.

Montana State College

Papers were given by five seniors on current topics. October 7. Attendance 98.

Abstracts from Engineering Periodicals were given by five seniors. October 14. Attendance 120.

Edison Day program. October 21. Attendance 118.
Western Electric films were shown. October 28. Attendance 228.

University of North Carolina

Short talks were given by Messrs. Kieth Grady, C. E. Day, J. W. Hodges, B. C. Cooper, C. L. Jones and T. B. Smiley, students. October 23. Attendance 36.

Evolution of Modern Radio, by H. L. Coe, and

The Effect of Oscillations in Single Circuit Regenerative Radio Receivers, by Professor P. H. Daggett. November 6. Attendance 28.

University of North Dakota

Business Meeting. October 12. Attendance 16.

Ohio Northern University

Electrical Transmission of Photographs, by Mr. Wadsworth, and *Electrical Ore Cranes*, by Mr. Grace. October 22. Attendance 39.

Electrical Ship Repulsion, by Max Lee.
Motor Testing, by Roy Windum. November 5. Attendance 32.

Ohio State University

Business Meeting. October 10. Attendance 42.

Investigation of Speech and Hearing, by G. B. Thomas, Western Electric Co. The talk was illustrated by moving pictures. October 25. Attendance 150.

Oklahoma University

Talks on their Summer Experiences were given by Messrs.

P. H. Robinson, J. L. Neal, L. M. Montgomery, Ralph Thornton and Professor E. R. Page. Refreshments were served. October 22. Attendance 21.

Oregon State Agricultural College

The Benefits Derived from Being a Member of the A. I. E. E., by Professor McMillan. October 30. Attendance 35.

Pennsylvania State College

Business Meeting. October 8. Attendance 26.
Smoker. Short informal talks were given. October 16. Attendance 43.

University of Pittsburgh

Business Meeting. The following officers were elected: Chairman, E. A. Casey; Vice-Chairman, D. S. Templeton; and Secretary-Treasurer, J. E. Lange. October 10. Attendance 25.

A talk was given by Mr. M. E. Skinner, Duquesne Light Co., in which he spoke of the work of the A. I. E. E. and assured the Branch of the support of the Pittsburgh Section. October 17. Attendance 29.

Automatic Train Control, by E. A. Casey.
Muscle Shoals—What It Is and What It Means to Us, by D. S. Templeton. October 24. Attendance 27.

Electric Blooming Mill Operation, by G. R. Boardman.
Application of Electricity in Mining, by A. T. Yaeckel. October 31. Attendance 28.

Rhode Island State College

Methods of Mining Copper in the Northern Peninsula of Michigan, by Professor William Anderson. The lecture was illustrated with slides. October 3. Attendance 17.

Transmission Lines and Remote Control, by Joseph M. Lamb, student. October 23. Attendance 17.

University of South Dakota

Business Meeting. The following officers were elected: President, Charles Barret; and Secretary, Harold Babb. November 6. Attendance 7.

Stanford University

Business Meeting. October 14. Attendance 13.
The Manufacture and Characteristics of High-Voltage Cable, by Mr. Wiedman. October 28. Attendance 16.

University of Tennessee

Business Meeting. The following officers were elected: President, Stephen R. Woods; and Secretary-Treasurer, Fred J. Guice. October 2. Attendance 12.

Facts about the New University 500 Kw. Power and Heating Plant, by W. R. Woolrich. October 16. Attendance 34.

University of Texas

Reorganization Meeting. The following officers were elected: President, O. Wolf; Vice-President, G. Calhoun; Secretary-Treasurer, A. V. Bedford. October 22. Attendance 20.

Virginia Military Institute

Business Meeting. Mr. J. P. Black was elected Secretary. September 15. Attendance 22.

Washington University

The Possibilities of Radio, by J. McNamee, Kennedy Radio Co. October 9. Attendance 42.

Business Meeting. Mr. C. Bunch was elected Treasurer. October 24. Attendance 12.

The Fynn Weichsel Motor, by Mr. Holston, Wagner Electric Co. The paper was illustrated with slides. November 6. Attendance 25.

University of Washington

The Engineer and His Achievements, by Professor Kirsten. October 14. Attendance 33.

West Virginia University

Automatic Fashover Protection, by Mr. Naylor, and
Facing the Facts in Regard to Rural Service, by Mr. Crush, and
Application of Automatic Substations to Central Station Service in Metropolitan Districts, by Mr. Reynolds, and
Character and Life of Steinmetz, by Mr. Smith, and
Electrification of the Virginia Railway, by Mr. Berry, and
Condition of the Electric Railway Industry, by Mr. Wolfe, and
Lightning Arrester Application, by Mr. Devebre, and
Gasoline Electric Car, by Mr. Robinson, and
Damming of Bear Creek, by Mr. Cole, and
Virginia Railway Electrification, by Mr. Witt, and
Life of B. G. Lamme, by Mr. Beardslee, and
Four Days on Bear Creek, by Mr. Worden. October 15. Attendance 21.
The Gasoline Electric Car, by Mr. Gramm, and
What Does Interurban Railway Mean to the Economic Development of the Middle West, by Mr. Meintell, and
Protective Relays, by Mr. Kisner, and
Gas Engines in Municipal Light Plant, by Mr. Neill, and
Water Power, by Mr. Pike, and
The Care of Transformers, by Mr. Pitzenberger, and
Importance of Efficient Lubrication for Railway Motors, by Mr. Henderson, and
Rates for Buying in this State, by Mr. Jones.
What the Interurban Railway Means to the People of the Middle West, by Mr. Lambert, and
The Oscillograph, by Mr. Mountain, and
Elimination of Noise in Electrical Traction, by Mr. Osborne. October 22. Attendance 21.
The 65,000 Kv. Generator of the Niagara Power Station, by Mr. Reynolds, and
The Importance of Sufficient Lubrication for Railway Motors, by Mr. Crush, and
Operating Conditions of Transformers, by Mr. Smith, and
The Yargh River Power Development, by Mr. Wolfe, and
Latches and Operating Sticks for Disconnecting Switches, by Mr. Naylor, and
Internal Combustion Electric Locomotives, by Mr. Devebre, and

Industrial Research, by Mr. Robinson, and
Peak Voltage Measurements, by Mr. Witt, and
Electric Furnace in the Brass Industry, by Mr. Beardslee, and
William Spencer Murray, by Mr. Worden, and
Opportunities for the Inventor, by Mr. Cole, and
Economies in Railway Maintenance, by Mr. Berry, and
Essentials of Transformers, by Mr. Lambert. October 29. Attendance 23.

University of Wisconsin

Business Meeting. The following officers were elected: Chairman, R. R. Benedict; Secretary-Treasurer, H. E. Reinhold; Executive Committee, B. Steel and V. Thieman. October 22. Attendance 125.

Yale University

Informal Reunion. Refreshments were served. October 15. Attendance 51.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will, it is hoped, be sufficient, not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

TECHNICAL GRADUATES, two, with two to three years' experience in maintenance and testing of relays on overhead high-tension transmission lines. Apply by letter giving detailed information of experience and salary desired. Location, Indiana and Ohio. R-4780.

SALES ENGINEER for Kansas City, strictly commission basis for manufacturers of carbon brushes. R-2954.

DESIGNER, low power transformer, technical graduate who has had at least two or three years' experience. Location, Massachusetts. R-4639.

ELECTRICIAN FOREMAN, to lay out and take full charge of 2300 to 4000 volts distribution system. Salary $200 a month and expenses. Location, Cuba. R-5021.

MECHANICAL ENGINEER, to design gasoline railway passenger cars. Preferably one who is familiar with street railway car construction and gasoline engines, clutches, transmission, etc. Must be willing to do some board work. Opportunities. Apply by letter giving experience and references. Location, N. C. R-4897.

SUBSTATION OPERATORS, experienced high tension switchboard operators for utility company. In applying give past experience, references, age, education and salary expected. Location, New York. R-5065.

ENGINEER, for research work in infiltration, who is familiar with the methods of figuring heat losses and the consequent radiation or warm air inlets necessary to overcome these heat losses. Must be able to write or supervise the writing of literature on the subject and present the matter to architects and engineers and, at the same time, train salesman to carry on the work. Must be able to address a body of architects, engineers and piping contractors and talk about his subject and convince his listeners that he is right. Location, Missouri. R-5053.

MEN AVAILABLE

ENGINEERING GRADUATE 1921 B. S., (E. E.) and post graduate work, age 30, Assoc. A. I. E. E. Have had eight years' experience in various branches of electrical engineering such as wiring, installation and maintenance of D. C. and A. C. motors and generators as well as testing. Two years' teaching experience as instructor in electrical engineering subjects. Highly interested in transmission work and original investigations and research. Available on short notice. B-8886.

HYDRO-ELECTRIC ENGINEER desires temporary or permanent connection with power company, construction company, or consulting engineer. Graduate European university, degree E. E. Familiar with efficient power plant and transmission line operation, inspecting, testing and installing hydraulic and electric machinery, layout work, reports, research work. Twenty years of wide experience. B-8888.

ENGINEER with native electrical and mechanical ability in theory and practise, desires to communicate with anyone requiring the services of a man who can be depended upon in taking responsibility. Technical graduate, G. E. test, and has record of eight years' steady advancement to present position as superintendent of 12,000 kilowatt hydro-electric power and pumping system, with 150 miles high tension transmission lines. B-8881.

YOUNG MAN, 24, desires position with a future. Experienced in maintenance and construction on industrial and power station equipment. Would like to connect with engineering construction company, or start in sales engineering. At present employed but desires to change. Location, middle Atlantic States. B-8903.

ELECTRICAL ENGINEER, age 24, married, two years' experience in testing, service and assistant foreman of test department with firm manufacturing motor and generators A. C. and D. C. Desires work in sales, maintenance or in engineering department of private concern. Available short notice. B-8907.

GRADUATE ELECTRICAL ENGINEER, age 25, married, three years' experience in power house design and layout work, desires position along sales or engineering lines with a concern in California. B-7190.

ELECTRICAL ENGINEER with Bachelors and Masters degrees, age 32, married, desires position in engineering department of industrial concern. Three year's G. E. Test experience and four years inspection, construction and maintenance of power plants, substations, power-lines, switchboards electric locomotives and miscellaneous motor drives. At present employed. B-7065.

GRADUATE ELECTRO-CHEMIST, married, experienced in the engineering supervision and production of carbon and metal brushes, desires to better position. Will consider any opportunity along allied lines. B-8910.

ELECTRICAL ENGINEER, technical graduate, age 25, desires position in engineering department of industrial plant, preferably steel mill, or a public utility company. Now employed in the engineering department of a large electrical manufacturing company having finished the prescribed course for graduate students and having had over one years' experience in the application of electric equipment to the industry. Location preferred, Southern states. B-8918.

ELECTRICAL ENGINEER, M. I. T., age 26, unmarried. Five years of engineering and one-half year of sales experience. Desires position with construction and operating company, preferably hydroelectric. Would locate anywhere in U. S. or Canada. Available on short notice, minimum salary $2300. B-8933.

ENGINEER, at present representative of large company. Fourteen years' experience in supervision, construction, operation, investigation. Desires position with industrial concern, or as electrical executive non-technical organization. Clean record. B-3633.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, age 33, married, Protestant. Broad experience of twelve years, comprising five years steel mill production and maintenance, two years U. S. Navy, two years anthracite coal industry, two years power plant construction, one year valuation of public utilities. Desires permanent position assuring permanent residence with steel mill or public utility. B-8935.

ELECTRICAL MECHANICAL ENGINEER, wide experience in the design, installation and rehabilitation of industrial plants, seeks a suitable connection as chief engineer, superintendent of

plants, chief electrician, master mechanic, on actual work or in a consulting capacity. Could devote entire or part of his time. Will take financial interest if desirable. B-8327.

YOUNG EXECUTIVE open for engagement, single, present salary $3800 per year. Management and superintendency of electrical properties eight years. Experience covers executive duties, designing and construction of substations, transmission and distribution systems. Available on thirty days' notice. B-8319.

SALES ENGINEER OR FACTORY EXECUTIVE, experienced in design, production, factory management and sales work. Qualified to represent manufacturer of mechanical or electrical equipment or supplies requiring technical demonstration. Expert in designing apparatus for quantity production, or to meet special conditions. Broad experience dealing with executives and engineers. B-3061.

MICHIGAN GRADUATE 1924, would like to grow in experience with a growing public utility, preferably in the Western States. B-8472.

ELECTRICAL ENGINEER, graduated in Germany. Over twenty years' experience in Europe and the Far East; executive, underground and overhead high voltage transmission, distribution, installation of power plant machinery, electrical mining equipment. Desires to make connection with concern of standing, in U. S. or abroad. B-8858.

ELECTRICAL ENGINEER, university graduate, young, ambitious, industrious, inventor, single, speaking three languages. Two years' experience in testing, designing, research and manufacturing of electrical and radio apparatus, twenty-two months central station operation, distribution and testing. Desires connection with electrical, radio or public utilities concern recognizing ability. Salary secondary importance. Available immediately. B-7178.

ELECTRICAL GRADUATE, seven years' experience manufacturing, testing, supervising erection of electrical power apparatus and switching equipment. Thoroughly familiar with automatic power control and remote metering. Desires position as electrical engineer or construction superintendent with manufacturing or utility company. Now available. Location immaterial. B-8971.

ELECTRICAL ENGINEER, 1918, six years' experience in work connected with central station industry, also radio experience. Desires engineering or sales work. B-5226.

GRADUATE ENGINEER, industrial, mechanical or construction, E. E. degree 1915, age 32. Experience; two years' test work with G. E. Company, six years' industrial, including time study, rate setting, efficiency and production work, two years' maintenance and construction. Available on short notice. Vicinity of New York City preferred, others considered. Married. B-3199.

ENGINEER EXECUTIVE, age 28, M. I. T. '18, desires connection with New England enterprise along industrial or production engineering lines. Has had shop, sales and executive experience. Good knowledge of manufacturing methods, industrial equipment, electric power applications and men. B-8978.

ELECTRICAL ENGINEER, 28, single, graduate Dartmouth '20, B. S., post graduate Columbia '23, E. E. Experience; one year Bell Telephone, transmission. Desires position with electric power company. Location, Philadelphia or vicinity. Available immediately. B-8977.

TECHNICAL GRADUATE in chemistry and electrical engineering; American, age 30. Twelve years' experience which includes work in government, college and industrial laboratories along research and experimental lines. Prefer position as research assistant or instructor with opportunity to continue studies, but other openings will be considered. B-8987.

TECHNICAL GRADUATE, age 26, two years' test floor experience with Westinghouse E. & M. Company. At present employed in their electrical service engineering department. Desires position with public utility or industrial concern. Available on two weeks' notice. Location immaterial. B-8985.

ELECTRICAL ENGINEER, desires connection with holding company to report on electrical system. Economics, especially in regard to transmission and distribution. Twenty years' experience in design, construction and operation of central station system. B-8986.

ELECTRICAL ENGINEER, age 32, married, seeks position in East with electrical manufacturing concern. Five years' experience in telephone and radio, four years in high voltage electrical porcelain manufacture. Salary $3500. A-4453.

ELECTRICAL GRADUATE, ten years' experience mostly structural, thirteen years' radio experimenter. Excellent personality and some knowledge of salesmanship. At present assistant chief engineer small manufacturing concern and in responsible charge of work for five years. Will consider any position with good opportunities in sales engineering work. Prefer New York City. Available January first. B-8967.

METERMAN OR GENERAL SERVICE METERMAN, age 36, experienced in single, polyphase and D. C. Watthour meters. Testing, repairing, maintenance all types and makes. Experience in A. C. and D. C. armature winding. Repairman all electrical apparatus, wireless telegrapher, interior wireman, lineman, estimates. Training; three years' I. C. S., one year Westinghouse Technical Night School, thirteen weeks Carnegie Institute. Available two weeks' notice. B-8984.

TECHNICAL GRADUATE, B. S. in E. E., 25, single. Eighteen months' Westinghouse Electric including graduate student course, engineering school, switchboard engineering work. Desires connection reliable consulting engineer, progressive public utility, or industrial concern with opportunity for one who has ability, reliability, and good personality. Unquestionable references. Employed. Available reasonable notice. B-8991.

INDUSTRIAL OR SALES, graduate electrical engineer with five years' experience on testing floor, shops and sales organization of two leading electrical manufacturing companies. Interested only in permanent position offering opportunity. At present employed. Available January 1, 1925. B-8945.

MECHANICAL AND ELECTRICAL ENGINEER, (University of Zurich and Berlin), experienced in designing and equipping all kinds of power plants and in heating design, seeks position as designer along these lines, preferably in an organization where technical, economical problems come up. B-8406.

ELECTRICAL ENGINEER, graduate, two years' experience since graduation in experimental and road work. Desires permanent position with no traveling, in New York or Ohio. B-8996.

YOUNG MAN, age 24, will graduate in January 1925 with degrees of B. S. of E. E. Desires connection with consulting engineers or public utility concern. Wants something permanent and with a future for hard worker. Will go anywhere. B-9001.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED NOVEMBER 1, 1924

ALDRICH, KENNETH BURLINGHAM, Electrical Engineer, Puget Sound Power & Light Co., Tacoma, Wash.

*ALPERN, DWIGHT K., Student, Massachusetts Institute of Technology, Cambridge, Mass.; for mail, New York, N. Y.

ATTARIAN, EDWARD GEORGE, Electrical Tester, Brooklyn Rapid Transit Testing Bureau, 500 Kent Ave., Brooklyn, N. Y.

BREARLEY, REGINALD JOHN, Electrician Shawinigan Water & Power Co., Shawinigan Falls, P. Q., Can.

BROWN, THOMAS, Tester, Habirshaw Electric Cable Co., Yonkers; res., New York, N. Y.

CHURCH, JOSEPH OSCAR, Electrician, Walsh & Weidner Boiler Co., Chattanooga; res., East Chattanooga, Tenn.

COLE, WILL G., Armature Winder, Westwood, Calif.

COTTELL, VICTOR GODLY, Electrician, Constr. Dept., New York Edison Co., 34 E. 26th St., New York, N. Y.

DAVIDSON-ARNOTT, THOMAS, President, Davidson-Arnott & Co., Ltd., Marine Sq., Port of Spain, Trinidad, British West Indies.

GLASSFORD, CHESTER GRANVILLE, Facility Engineer, The Pacific Tel. & Tel. Co., 335 Fell St., San Francisco, Calif.

GOLDINER, ARTHUR C., 236 Prospect Park West, Brooklyn, N. Y.

HACKETT, GEORGE RICHARD, Test Man, General Electric Co., Baltimore, Md.

HANNAH, GEORGE MORRISON, Plant Instructor, Chesapeake & Potomac Tel. Co., 3913 Kate Ave., Baltimore, Md.

HUBBARD, ALFRED M., Electrical Engineer, Radium X-Ray Co., 1026 L. C. Smith Bldg., Seattle, Wash.

HUGHES, GUY NEWTON, Chief Electrical Engineer, W. E. Biggs Engineering Co., 714 Holston Bank Bldg., Knoxville, Tenn.

KAHN, JULIUS LEWIS, 202 South St., Oyster Bay, N. Y.

KELLS, DAVID GIRVIN, Tester, New York, Edison Co., 92 Vandam St., New York; res., Brooklyn, N. Y.

LARSSEN, EDWARD OTTO, Operator, British Columbia Electric Ry. Co., Vancouver, B. C., Can.

LOWE, LEONARD LEE, Chief Electrician, U. S. Cast Iron Pipe Foundry Co., 19th & Whiteside Sts., Chattanooga; res., East Chattanooga, Tenn.

MAGEE, CHARLES WILLIAM, 32 Undercliff St., Yonkers, N. Y.

MASSHARD, HANS J., Electrical Draftsman, Public Service Production Co., 54 Park Place, Newark, N. J.

MAURER, ANTHONY ARTHUR, Testing Laboratory, Western Electric Co., Inc., Hawthorne, Chicago, Ill.

*McCREARY, HAROLD JAMES, Inspection Methods Engineer, Western Electric Co., Inc., 22nd St. & Cicero Ave., Chicago, Ill.

McGEE, JOHN EVAN, Laboratory Assistant, Mtl. & Proc. Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

McGILVRAY, JOSEPH R., Electrical Inspector, Gibbs Brothers, Inc., 1 Broadway, New York, N. Y.; res., Quincy, Mass.

MEIJER, W. A. R., Agent for Hengelosche Electrische & Mechanische Apparaten, 1a Capuchinas 23, Apartado 481, Mexico, D. F., Mex.

MERCHANT, TRIBHOVANDAS BHUGVANDAS, College of Technology, Manchester, Eng.

MOCKEL, ROBERT, Asst. Engineer, Brooklyn Edison Co., Pearl & Willoughby Sts., Brooklyn, N. Y.

MOTSEK, PETER, Electrician, Tkach & Motsek, 40 Greene St., Jersey City, N. J.

NAUDAIN, MORGAN C., Electrical Dept., American Sheet & Tin Plate Co., 112 Farragut Ave., Vandergrift, Pa.

NOBLE, NEWTON A., Telephone Engineer, Western Electric Co., Inc., Hawthorne Sta., Chicago, Ill.

NUTTER, LAWRENCE HOWARD, Central Station Engineering Dept., General Electric Co., Schenectady, N. Y.

O'BRIEN, FREDRIC GORDON, 186 Ege Ave., Jersey City, N. J.

O'BRIEN, PAUL, Electrician, Manhattan Eye, Ear & Throat Hospital, 210 E. 64th St., New York, N. Y.

ORTMANN, FREDERICK JOHN, Electric Construction & Maintenance Foreman, Eastern Connecticut Power Co., Norwich, Conn.

PARINO, RAFAEL Q., Chief Electrician, Philippine Refining Corp., Cebu, Cebu, P. I.

PARKER, MERTON C., Electrical Engineer, Columbia Tire Corp., 116 Columbia Blvd., Portland, Ore.

PERRETEN, ARNOLD E., Field Engineer, Public Service Co. of Colo., 1922-12th St., Boulder, Colo.

PILSBURY, CLINTON C., Sales Engineer, General Electric Co., 100 Woodlawn Ave., Pittsfield, Mass.

REGUENGA, ISIDORO MANUEL, Design Supervisor, Electric Bond & Share Co., 65 Broadway, New York; res., Brooklyn, N. Y.

REYDON, HENRY, Electrical Draftsman, Public Service Production Co., 54 Park Place, Newark, N. J.

RICE, WILLIAM BAYARD, Asst. Chief Inspector, Western Electric Co., Inc., 1100 W. York St., Philadelphia, Pa.

RICKERD, CECIL W., Electrical Engineer, Dwight P. Robinson & Co., Inc., 125 E. 46th St., New York; res., Peekskill, N. Y.

SAMUEL, RENE ADRIEN PAUL, Engineer, Compagnie du Chemin de fer Paris-Orleans, 41 Boulevard de la Gare, Paris (13°), France.

*SCHULZE, HARLEY C., Testing Dept., General Electric Co., Schenectady, N. Y.

SEIPPEL, CLAUDE P., Electrical Draftsman, Electic Bond & Share Co., 71 Broadway, New York, N. Y.

SEPULVEDA, HIPOLITO, Station Electrician, Mexican Light & Power Co., Necaxa, Puebla, Mexico.

SMITH, HOWARD JOHN, Operator, Western Electric Co., Inc., 463 West St., New York, N. Y.

TATE, DODDRIDGE CALVIN, Telephone Engineer, Western Electric Co., Inc., Hawthorne Station, Chicago; res., Oak Park, Ill.

THOMSON, HENRY, Draftsman & Designer, New York Edison Co., 130 E. 15th St., New York, N. Y.

TOZIER, EDWIN STONE, Electrical Inspector, Electrical Dept., Eastman Kodak Co., Kodak Park, Rochester, N. Y.

VIDAL, HENRI B., Salesman, Westinghouse Elec. & Mfg. Co., Niagara Falls, N. Y.

WU, WEI CHOU, Electrical Engineer, Commonwealth Power Corp., Jackson, Mich.

Total 53

*Formerly Enrolled Students.

ASSOCIATES REELECTED NOVEMBER 1, 1924

BALLMAN, EDWIN C., President, Balder Electric Co., 4353 Duncan Ave., St. Louis, Mo.

CALLAHAN, EDWARD FRANCIS, Sales, Manager, Dept. of Americas, International General Electric Co., Inc., Schenectady, N. Y.

DAVISON, ROBERT THOMAS, Chief Electrical Engineer, Cia Industrial de Orizaba S. A., Rio Blanco, Ver., Mex.

HEADINGS, WILLIAM WADE, Chief Engineer, Pittsburgh Reflector Co., 402 Bowman Bldg., 3rd & Ross Sts., Pittsburgh, Pa.

HILLEGASS, HERBERT H., Engineering Assistant, The Bell Telephone Co., of Penna. 261 N. Broad St., Philadelphia; res., Abington, Pa.

MURDOCK, ALFRED WILLIAM, Asst. Engineer, Hydro-Electric Power Commission, 190 University Ave., Toronto, Ont., Can.

PAINE, ROY McGREGOR, Engineer in Charge of Substation, British Columbia Electric Railway Co., Vancouver, B. C., Can.

MEMBERS REELECTED NOVEMBER 1, 1924

EASTERBROOK, JOHN F., Yale Club, 50 Vanderbilt Ave., New York, N. Y.

HILL, WILLIAM WELCH, Graduate Work, Johns-Hopkins University, 2745 Maryland Ave., Baltimore, Md.

MEMBERS ELECTED NOVEMBER 1, 1924

FISHER, WILLIAM CLAUDE, Chief Electrical Engineer, Westchester Lighting Co., Mount Vernon, N. Y.

HYNES, LEE POWERS, President, Hynes & Cox Electric Corp.; Consulting Engineer, Consolidated Car Heating Co., 36 State St., Albany, N. Y.

INGHAM, FRANCIS ERNEST, Sales Engineer, Westinghouse Electric International Co., 150 Broadway, New York, N. Y.

LEHR, EDWIN E., Section Engineer, Motor Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Pittsburgh, Pa.

LYONS, NICHOLAS D., A. Edgar Goetze, Inc., 56 Park Place, New York, N. Y.

WITTENBERG, MICHAEL, 115 E. Mosholu Parkway North, New York, N. Y.

TRANSFERRED TO GRADE OF MEMBER NOVEMBER 1, 1924

GREENWOOD, LEON H., Telephone Engineer, American Telephone & Telegraph Co., New York, N. Y.

MILLER, HERMAN P., Jr., Radio Engineer, Federal Telegraph Co., Palo Alto, Calif.

STRAUS, HENRY L., Member of Firm, Industrial Power Equipment Co., Baltimore, Md.

THATCHER, RENO E., Service Superintendent, Puget Sound Power & Light Co., Seattle, Wash.

WOODRUFF, LOUIS F., Instructor in Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

YOE, HARRY A., Assistant Engineer, New York Central Railroad Co., New York, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before December 31, 1924.

Abraham, L. G., American Tel. & Tel. Co., New York, N. Y.

Aldunate, A., 134 W. 85th St., New York, N. Y.

Alliman, C. L., East Penn Electric Co., Pottsville, Pa.

Alling, V. B., Law Student, 299 Broadway, New York, N. Y.

Banghart, E. S., Pittsburgh Transformer Co., New York, N. Y.

Basta, C., New York Edison Co., New York, N. Y.

Belt, A. M., Potomac Power Co., Washington, D. C.

Benson, O. B., Edison Elec. Illuminating Co. of Boston, Boston, Mass.

Blackburn, L. S., Westinghouse Elec. & Mfg. Co., Oakland, Calif.

Blanchard, K. E., Public Service Railway Co., Newark, N. J.

Blommer, S. G., Cutler-Hammer Mfg. Co., Milwaukee, Wis.

Blose, H. S., Pennsylvania Power & Light Co., Hazleton, Pa.

Bochenko, S. J., New York Edison Co., New York, N. Y.

Borst, J. A., Interborough Rapid Transit Co., New York, N. Y.

Bourke, H., General Electric Co., Erie, Pa.

Bradley, D. B., Western Electric Co., Inc., Philadelphia, Pa.

Bresmer, F. G., Potter Electric Construction Co., St. Louis, Mo.

Browning, C. L., General Electric Co., Chicago, Ill.

Burk, A., Dubilier Condenser & Radio Corp., New York, N. Y.

Burrill, C. M., General Electric Co., Schenectady, N. Y.

Canariis, S. A., Dixie Construction Co., Birmingham, Ala.

Cano, H. W., Secretary, Percy H. Thomas, New York, N. Y.

Carlson, C. M., St. Paul Gas Light Co., St. Paul, Minn.

Carpenter, E. S., (Member), Central Illinois Public Service Co., Marion, Ill.
(Applicant for re-election.)

Cassedy, W. F., Jr., S. Stroock & Co., Inc., Newburgh, N. Y.

Chen, C. H., General Electric Co., Schenectady, N. Y.
(For mail, Nanking, China.)

Child, R. S., Bonbright & Co., New York, N. Y.

Childerhose, E. A., Pennsylvania Water & Power Co., Baltimore, Md.

Chilton, W. H., Roanoke Railway & Electric Co., Roanoke, Va.

Clarke, A. M., Portland Electric Power Co., Portland, Ore.

Cochran, W. P., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.

Conley, W. J., Murrie & Co., New York, N. Y.

Cope, K. H., Wagner Electric Corp., St. Louis, Mo.

Cords, F. W., Cutler-Hammer Mfg. Co., Milwaukee, Wis.

Cota, P. N., Central Wireless Station of Chapultepec, Chapultepec, Mexico, D. F., Mex.

Courson, W. O., General Electric Co., Erie, Pa.

Cowley, H., Electrical Engineering Bureau, Brooklyn, N. Y.

Croswaithe, J. S., 779 Warburton Ave., Yonkers, N. Y.

Curdts, E. B., Roanoke Rapids Power Co., Roanoke Rapids, N. C.

Das, M. M., Delta Star Electric Co., Chicago, Ill.

Day, T., General Electric Co., Minneapolis, Minn.

Dement, W. F., R. F. D. No. 8, Los Angeles, Calif.

De Santis, A. J., Upper Hudson Electric & R. R. Co., Catskill, N. Y.

Diller, C. O., Dallas Power & Light Co., Dallas, Texas

Dokas, K. B., Automatic Electric Co., Chicago, Ill.

Drumm, S. L., Phoenix Utility Co., New Orelans, La.

Dwinell, C. I., Cleveland Union Terminals Co., Cleveland, Ohio

Edwards, E. P., (Member), General Electric Co., Schenectady, N. Y.

Eggan, H. R., The Pacific Tel. & Tel. Co., San Francisco, Calif.

Elderkin, J. K., Chief Engineer, 272 New St., Newark, N. J.

El-Kordy, I. H., Radio Corp. of America, New York, N. Y.

Ellis, F. C., (Member), Research Engineer, Chicago, Ill.

Fallon, E. L., Stone & Webster, Inc., Boston, Mass.

Fatig, R. S., The Ohio Power Co., Newark, Ohio

Ferguson, E. F., Ohio State University, Columbus, Ohio

Ferrand, E. A., Brooklyn Edison Co., Brooklyn, N. Y.

Fisher, C. C., Public Service Production Co., Newark, N. J.
Forbes, H. C., New York Edison Co., New York, N. Y.
Foster, H. F., Consumers Power Co., Grand Rapids, Mich.
Frost, E. E., Contractor, Fort Worth, Texas
Gaffeney, C. H., (Member), Central Railroad of New Jersey, Jersey City, N. J.
Germain, H. A., General Electric Co., Pittsfield, Mass.
Gibson, P. F., Western Electric Co., Inc., New York, N. Y.
Gills, J. P., Appalachian Power Co., Bluefield, W. Va.
Grant, J. D., Stone & Webster, Inc., Terre Haute, Ind.
Grelick, D., General Electric Co., Pittsfield, Mass.
Grover, L. P., Interstate Public Service Co., Indianapolis, Ind.
Hamm, L. L., So. California Edison Co., Los Angeles, Calif.
Hannen, C. A., Bucyrus Co., South Milwaukee, Wis.
Hanner, R. A., General Electric Co., Pittsfield, Mass.
Hanners, W. H., Jr., American Tel. & Tel. Co., New York, N. Y.
Hart, H. W., Signal Corps, U. S. A., Washington, D. C.
Hart, W. A., Pinellas Power Co., Clearwater, Fla.
Hartman, W. A., New England Tel. & Tel. Co., Boston, Mass.
Hawkins, A. W., Public Service Electric Co. of N. J., Newark, N. J.
Hedeby, H. U., General Electric Co., Pittsfield, Mass.
Henke, H. E., St. Paul Gas Light Co., St. Paul, Minn.
Henkin, H., New York Edison Co., New York, N. Y.
Hentz, C. E., Mass. Institute of Technology, Cambridge, Mass.
Herbert, J. F., Jr., Baltimore Copper Works, Canton, Baltimore, Md.
Hill, O. E., Western Electric Co., Inc., Philadelphia, Pa.
Hills, H. W., Mass. Institute of Technology, Cambridge, Mass.
Hines, H. R., H. R. Hines Electric Co., Warsaw, Ind.
Hobart, E. A., Hobart Bros. Co., Troy, Ohio
Hornbeck, S. V., Hornbeck & Hardie Electric Co., St. Louis, Mo.
Ingalls, C. E., Factory Representative, San Francisco, Calif.
Jeffs, A. J., The English Electric Co., Ltd., St. Catharines, Ont., Can.
Jennings, F. W., General Electric Co., Schenectady, N. Y.
Johnson, S. J., Brooklyn Edison Co., Brooklyn, N. Y.
Keith, C. R., Western Electric Co., Inc., New York, N. Y.
Kettner, A. E., General Electric Co., Schenectady, N. Y.
King, F. W., Union Electric Light & Power Co., Webster Groves, Mo.
King, R. A., General Electric Co., Erie, Pa.
King, T. T., General Electric Co., Fort Wayne, Ind.
Kinnamon, L. B., Central Hudson Gas & Electric Co., Poughkeepsie, N. Y.
Kvist, D. A., General Electric Co., Pittsfield, Mass.
Laird, A. G., Western Electric Co., Inc., New York, N. Y.
Lane, T. W., Western Electric Co., Inc., Philadelphia, Pa.
Larsen, T., 49 Sidney Place, Brooklyn, N. Y.
Lesko, S. F., Jr., Stephen Lesko & Son, Bridgeport, Conn.
Lewis, H. M., Pacific Gas & Electric Co., San Francisco, Calif.
Lillibridge, C. G., F. R. Jennings Co., Detroit, Mich.
Lind, L., New York Telephone Co., New York, N. Y.
Low, M. C., New England Tel. & Tel. Co., Boston, Mass.
MacLean, K. D., (Member), Day & Zimmerman, Inc., Philadelphia, Pa.
Markley, W. F., Western Union Telegraph Co., New York, N. Y.
Maxwell, T., United Electric Light & Power Co., New York, N. Y.
McMurry, F. R., Western Electric Co., New York, N. Y.
McRell, H. F., General Electric Co., Pittsfield, Mass.
McVean, N. S., New England Tel. & Tel. Co., Boston, Mass.
McWethy, H. E., (Member), Railroad & Warehouse Comm., St. Paul, Minn.
Meredith, C. C., Radio Engineer, Toronto, Ont., Can.
Miklos, J., Charles Eisler Engineering Corp., Newark, N. J.
Millar, W., Canadian Westinghouse Co., Vancouver, B. C.
Miller, H. P., Pratt Institute, Brooklyn, N. Y.
Mitchell, L. F. A., Fairbanks, Morse & Co., New York, N. Y.
Molohon, F. L., General Electric Co., Schenectady, N. Y.
Mooney, J. T., Agricola y de Fuerza Electrica del Rio, C. Camargo, Chihuahua, Chih., Mex.
Moore, R. E., Western Electric Co., Inc., Cincinnati, Ohio
Morris, J. A., Northeastern University, Boston, Mass.
Morrison, L. A., Globe Radio Equipment Co., New York, N. Y.
(Applicant for re-election)
Morton, W. B., Pacific Gas & Electric Co., San Francisco, Calif.
Obregon, G., Jr., Mexican Tel. & Tel. Co., Mexico, D. F., Mex.
O'Neil, P., Municipal Engineering Co., Dallas, Texas
Owen, E., Knox Process Corp., New York, N. Y.
Pals, T., United Light & Power Co., Davenport, Iowa
Paul, C. H., St. Paul Gas Light Co., St. Paul, Minn.
Phillips, H. B., (Member), Mass. Institute of Technology, Cambridge, Mass.
Porter, L. G., Monongahela West Penn Public Service Co., Fairmont, W. Va.
Rayl, C. C., American Tel. & Tel. Co., Cleveland, Ohio
Richards, H. E., Northeastern University, Boston, Mass.
Roberts, S., Columbus Railway, Power & Light Co., Columbus, Ohio
(Applicant for re-election)
Rogers, A. C., Appalachian Power Co., Beulfield, W. Va.
Salisbury, H. D., Tennessee Coal, Iron & R. R. Co., Birmingham, Ala.
Saul, A. P. H., Robertson-Cataract Electric Co., Buffalo, N. Y.
Sayler, M. D., Commercial Electrical Supply Co., St. Louis, Mo.
Scarr, H. F., Western Electric Co., New York, N. Y.
Shaw, F. M., Electrician, 348 White Plains Road, New York, N. Y.
Sipley, L. W., (Member), Crescent Truck Co., Philadelphia, Pa.
Sirms, W. J., Western Electric Co., Inc., Philadelphia, Pa.
Smith, E. W., The Potomac Edison Co., Hagerstown, Md.
Smith, H. A., American Tel. & Tel. Co., New York, N. Y.
Smith, L. H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Smith, R. P., Westinghouse Elec. & Mfg. Co., Richmond, Va.
Smith, R. S., New York Edison Co., New York, N. Y.
Spalding, D. A., British Columbia Electric Railway Co., Vancouver, B. C.
Sproule, J. E., Hydro-Electric Power Commission, Toronto, Ont., Can.
Stamper, G., The Union Gas & Electric Co., Cincinnati, Ohio
Sternad, W. J., Tiffany Electric Co., Inc., Jersey City, N. J.
Stewart, D. J., D. J. Stewart & Co., Rockford, Ill.
Stockton, C. B., United Electric Light & Power Co., New York, N. Y.
Temkin, M., Keystone Engineering Co., Reading, Pa.
Tjoflat, G. B., Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.
Townshend, B., International Machines Corp., New York, N. Y.
Tranchina, P., New York Edison Co., New York, N. Y.
Tufts, J. B., Electric Motor Repair Co., Springfield, Mass.
Turner, W. F., Wisconsin Power & Light Co., Monroe, Wis.
Vandestadt, H. J., General Electric Co., St. Louis, Mo.
Vetri, L., New York Edison Co., New York, N. Y.
Vincens, E., Wilder Electric Trust, New York, N. Y.
von Mehren, O., New York Edison Co., New York, N. Y.
Walker, J. F., General Electric Co., Schenectady, N. Y.
Walsh, F., Alaska Steamship Co., Seattle, Wash.
Werden, J., Western Electric Co., Inc., Jersey City, N. J.
White, L. C., Portland Electric Power Co., Portland, Ore.
Wicks, S. J., Steel Co. of Canada, Hamilton, Ont., Can.
Williams, F. M., Atlantic Refining Co., Point Breeze, Philadelphia, Pa.
Wilson, R. J., Dingle-Clark Co., Cleveland, Ohio
Woodhead, E. A., Idaho Power Co., Boise, Idaho
Wyks, J. W., Public Service Electric & Gas Co., Trenton, N. J.
Wylie, C. M., Brooklyn Edison Co., Brooklyn, N. Y.
Yagodkin, V. K., Stone & Webster, Inc., Boston, Mass.

Total 172

Foreign

Barnard, M. C., (Member), S. A. Railways, Pietermaritz, Natal, S. Africa
Clements, H., Chile Exploration Co., Chuquicamata, Chile, S. A.
Dodd, H. J., (Member), Broken Hill Associated Smelters, Port Pirie, South Australia
Font, M., Government of Porto Rico, Santurce, Porto Rico
Moreira, R. de Sa, Paulista Railway, Sao Paulo, Brazil, S. A.
Pershad, B., (Member), H. E. H., Nizam's Government, Hyderabad, Deccan, India
Pita, Rodrigo, Riegos y Fuerza del Ebro, Perida, Spain
Revington, W. D., Electric Tramways, Tramway Board, Christchurch, N. Z.
Rodrigues, J. R., B. B. C. I. Railway, Rutlam, Central India
Sharma, D. D., Ram Flour Mills, Ajermi Gate, Delhi, India
Shefford, J. H., Asst. Engineer, 22 & 23 Allsop St., London, N. W., Eng.
Stewart, J. M., Canterbury University College, Christchurch, N. Z.
Thomson, H. C. W., Metropolitan-Vickers Elec. Co., Ltd., Trafford Park, Manchester, Eng.
Weeks, F. F. A., Electrical Engineer, Bedfordshire, Eng.

Total 14

STUDENTS ENROLLED NOVEMBER 1, 1924

19108 Castner, Theodore G., Drexel Institute
19109 Hartigan, Richard M., Kansas State Agricultural College
19110 Lapsley, Smith H., Kansas State Agricultural College
19111 Higginbottom, H. H., Kansas State Agricultural College
19112 Hinshaw, Foster A., Kansas State Agricultural College
19113 Long, Thomas H., Kansas State Agricultural College
19114 Gates, Lloyd A., Kansas State Agricultural College
19115 Domoney, Lowell C., Kansas State Agricultural College
19116 Schultz, Richard A., Kansas State Agricultural College
19117 Hotchkiss, Allen G., Kansas State Agricultural College
19118 Bowman, K. K., Kansas State Agricultural College
19119 Rugh, Christian E., Kansas State Agricultural College
19120 Houghland, V. E., Kansas State Agricultural College
19121 Robinson, Charles V., Kansas State Agricultural College
19122 Johnson, Ramond J., Kansas State Agricultural College
19123 Brunkau, Fred A., Kansas State Agricultural College
19124 Rethmeyer, H. G., Kansas State Agricultural College
19125 Bickett, H. R., Iowa State College
19126 Phillips, W. Earl, University of Syracuse
19127 Nygren, Einer D., Kansas State Agricultural College
19128 Norrish, Vernon M., Kansas State Agricultural College
19129 Howell, William L., Kansas State Agricultural College
19130 Talbott, Francis H., Kansas State Agricultural College
19131 Wilbur, Arnold M., University of Iowa
19132 Craven, Claude L., Lafayette College
19133 de Lavel, Carl G., Jr., Stevens Institute of Technology
19134 Gabert, Arlin H., Lafayette College
19135 Thomas, George G., Iowa State College
19136 Alberti, H. O., Kansas State Agricultural College
19137 Larson, Emil E., Kansas State Agricultural College
19138 Raynesford, L. H., Kansas State Agricultural College
19139 Stewart, Glenn D., Kansas State Agricultural College
19140 Tuthill, Harry E., Kansas State Agricultural College
19141 Towner, Dean W., Kansas State Agricultural College
19142 Bauer, Paul S., Harvard University
19143 Cawdrey, Max M., University of Cincinnati
19144 Franklin, J. Wayne, Univ. of Cincinnati
19145 Journeaux, Didier, Cornell University
19146 Camp, J. Roy, Alabama Polytechnic Inst.
19147 Duran, Albert E., Alabama Poly. Inst.
19148 Murphy, Marion B., Alabama Poly. Inst.
19149 Nalley, Joel, Alabama Poly. Institute
19150 Phillips, Sidney H., Alabama Poly. Inst.
19151 Sherman, John P., Alabama Poly. Inst.
19152 Thompson, William A., Alabama Poly. Inst
19153 Wallace, William M., Alabama Poly. Inst.
19154 Collins, Millford E., Tri-State College
19155 Walker, Ralph, Kansas State Agri. Col.
19156 Coman, Morris S., Kansas State agri. Col.
19157 Harris, James B., Kansas State Agri. Col.
19158 McNiff, H. M., Kansas State Agri. Col.
19159 Price, William S., Kansas State Agri. Col.
19160 Strom, Clifford H., Kansas State Agri. Col.
19161 Tate, C. C., Kansas State Agri. Col.
19162 Whitehouse, Fred W., Lafayette College
19163 Bauer, Bertram, Drexel Institute
19164 Lissner, Earle P., Mass. Inst. of Tech.
19165 Stewart, Donald, McGill University
19166 Lewis, Floyd A., Syracuse University
19167 Pearson, Robert T., Syracuse University
19168 Bond, Floyd O., Oklahoma University
19169 Cooper, Crawford, Oklahoma University
19170 Cox, Arthur, Oklahoma University
19171 Hamrick, George R., Oklahoma University
19172 Hughes, R. F., Oklahoma University
19173 Kelso, Jay B., Oklahoma University
19174 Leech, Joseph S., Oklahoma University
19175 Parker, William M., Oklahoma University
19176 Robinson, Percy H., Oklahoma University
19177 Simonson, Lee, Oklahoma University
19178 Spence, Bruce G., Oklahoma University
19179 Tyler, Ralph A., Oklahoma University
19180 Whitcotten, Cecil W., Oklahoma Univer.
19181 Williams, Floyd J., Oklahoma University
19182 Chu, Wentworth, Harvard University
19183 Gandy, Benjamin B., Drexel Institute
19184 Shu, Ing Gee, Harvard University
19185 Taylor, Robert F., Drexel Institute
19186 Swift, Robert G., Drexel Institute
19187 Fulmer, John W., Lafayette College
19188 Pritchard, William R., Univ. of Toronto
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19190 Collier, Redus, Alabama Poly. Inst.
19191 Davis, James B., Alabama Poly. Inst.
19192 Garrett, W. A., Alabama Poly. Inst.
19193 Holmes, George F., Alabama Poly. Inst.
19194 Sledge, Robert B., Alabama Poly. Inst.
19195 Callen, Robert J., Jr., University of Illinois
19196 Cox, Robert D., University of Illinois
19197 Baseman, Elmer G., University of Illinois
19198 Bennett, Charles D., University of Illinois
19199 Hildenbrand, H. L., University of Illinois
19200 Hotchkiss, Raymond G., University of Ill.
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19202 Jascoviak, R. A., University of Illinois
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19228 Hecker, Alvin, Jr., University of Kansas
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19232 Pippitt, Paul F., University of Kansas
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19234 Potter, Ralph A., Yale University
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19238 Harris, Gerald N., Yale University
19239 Hanford, J. B., Yale University
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19241 Geer, Charles D., Yale University
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19247 Dickinson, Palmer L., Yale University
19248 Anderson, Theodore, Yale University
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19251 Stoner, Edmund C., Jr., Yale University
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19253 Johnson, Stanley T., Yale University
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19274 Adrian, Michael J., Univ. of Notre Dame
19275 Kelley, John A., Jr., Univ. of Notre Dame
19276 Rogge, Carlton A., Univ. of Notre Dame
19277 Alvarez, Ralph, University of Notre Dame
19278 Fischer, George H., Univ. of Notre Dame
19279 Austin, Ward H., University of California
19280 Bliss, M. Kennedy, University of California
19281 Brown, Edgar G., University of California
19282 Bush, Condon B., University of California
19283 Carney, Charles F., Univ. of California
19284 Dempster, Everett T., Univ. of California
19285 Dezzani, Maurice J., Univ. of California
19286 Edwards, Julian M., Univ. of California
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19288 Fiegel, John E., University of California
19289 Fallai, Homer J., University of California
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19293 Hamlin, Walter Thomas, Univ. of Calif.
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19305 McCann, Harold J., Univ. of California
19306 Meyer, Oscar C., University of California
19307 Potter, Ray M., Univ. of California
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19309 Randhawa, Saudagar S., Univ. of Calif.
19310 Read, Sidney, Jr., University of California
19311 Taylor, Clarence E., Univ. of California
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19313 Miller, Winfield D., Iowa State College
19314 Zubair, Mohammad, Univ. of Wisconsin
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19330 Andersen, Andrew, Armour Inst. of Tech.
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19401 Bates, Edwin T., University of Alabama
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19404 Comeaux, Clay E., University of Alabama
19405 Fishman, Solomon, Newark Technical
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19407 McGinn, G. Raymon, Kansas State Agricultural College
19408 Pirchio, Pasquale, Notre Dame University
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19410 Balleny, James L., McGill University
19411 Alvord, Carl G., Mass. Inst. of Tech.
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19413 Walsh, Harold E., Univ. of British Col.
19414 Weedfall, William W., University of Miss.
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19416 Connor, Carlyle A., University of Denver
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19418 Kelso, Rupert E., University of Denver
19419 McLaughlin, Robert R., Univ. of Denver
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19422 Weyerts, Edgar E., University of Denver
19423 Daniel, Richard G., Alabama Poly. Inst.
19424 Gray, William R., Alabama Poly. Inst.
19425 Lardent, Charlie L., Alabama Poly. Inst.
19426 Garlington, William L., Alabama Poly. Inst
19427 McArdle, James P., Jr., Alabama Poly. Inst
19428 McMullan, Charlie W., Alabama Poly. Inst
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19430 Quinn, Yancey M., Jr., Alabama Poly Inst.
19431 Ray, P. T., Alabama Poly. Institute
19432 Taylor, George H., Alabama Poly. Inst.
19433 Turner, Lucius McD., Alabama Poly. Inst.
19434 Wildern, John Malcolm, Alabama Poly. Institute
19435 Whitson, Raeburn C., Alabama Poly. Inst.
19436 Bostwock, J. Robert, Univ. of Washington
19437 Gardner, Harold A., Univ. of Washington
19438 Hartman, Jonathan E. Univ. of Wash.
19439 Klaus, Charles E., Univ. of Washington
19440 Lane, Glen L., University of Washington
19441 Lanning, Oscar D., Univ. of Washington
19442 Konzo, Seichi B., Univ. of Washington
19443 Nagamatsu, George R., Univ. of Wash.
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19447 Bailey, Robert E., University of Colorado
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19452 Holt, Lynn E., University of Colorado
19453 Lawrence, Edward C., Univ. of Colorado
19454 Pollard, James P., University of Colorado
19455 Smith, Leslie E., University of Colorado
19456 Swedlund, Lloyd E., Univ. of Colorado
19457 Thompson, Glenn E., Univ. of Colorado
19458 Chow, George C., Mass. Inst. of Tech.
19459 Cunliffe, Paul R., Newark Technical School
19460 Etter, Herbert, Drexel Institute
19461 Huffstutter, John W., Iowa State College
19462 Hooper, William H., McGill University
19463 Holmquist, Albert, Armour Inst. of Tech.
19464 Borgeson, Carl A., University of Illinois
19465 Brewer, L. David, University of Illinois
19466 Cronwell, Sven S., University of Illinois
19467 Elder, Clarence H., University of Illinois
19468 Gettel, George H., University of Illinois
19469 McMackin, Carl, University of Illinois
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19472 Richardson, Ralph L., Univ. of Illinois
19473 Ringness, Theodore R., Univ. of Illinois.
19474 Wallace, J. P., University of Illinois
19475 Wheeler, Clarence D., Univ. of Illinois
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19477 Beadle, Hector J., Penn. State College
19478 Bechtel, Walter W., Penn. State College
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19480 Beach, John M., Iowa State College
19481 Seaman, Henry, North Carolina State College of Agr.
19482 Mitchell, Adolph C., Penn. State College
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19485 Epstein, Malcolm B., Mass. Inst. of Tech.
19486 Lavo, Kenneth E., Penn. State College
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19493 Layman, Reuel D., University of Michigan
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19496 Paynter, Raymond P., Univ. of Michigan
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19500 Wambach, Albrecht G., Univ. of Michigan
19501 Wilson, Frederick E., Univ. of Michigan
19502 Burlingame, Leslie G., Rhode Island State College
19503 Davies, Edwin G., University of Toronto
19504 Freeland, William B., Penn. State College
19505 Kochler, William L., Penn. State College
19506 Krewatch, Albert V., Univ. of Delaware
19507 Tsao, Vong-san, Mass. Inst. of Tech.
19508 Smith, Merle W., University of Nevada
19509 Pffatteicher, Ernest P., Jr., Lafayette Col.
19510 Falkenstein, Louis F., Penn. State College
19511 Crawford, John D., Mass. Inst. of Tech.
19512 Haseman, Russell T., Purdue University
19513 Gunckel, Wade J., Purdue University
19514 Jones, Ray D., Purdue University
19515 Caldwell, J. A., Purdue University
19516 Worstell, Robert E., Purdue University
19517 Bellah, Levi T., Georgia School of Tech.
19518 Wood, James A., Georgia School of Tech.
19519 Whealler, J. Anson, Georgia School of Tech.
19520 Potts, William R., Georgia School of Tech.
19521 Barr, Tandy L., Georgia School of Tech.
19522 Dodds, Robert B., Jr., Georgia School of Technology
19523 Latimer, Cecil, Georgia School of Tech.

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DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies.

A. C. Combination Volt-Ammeter.—Bulletin A E-160. Describes a new combination volt-ammeter for alternating current. Roller-Smith Company, 12 Park Place, New York.

Safety Switch Condulets.—Bulletin. Describes safety switch condulets, tumbler type, for small motors or circuits of not more than 30 amperes. Crouse-Hinds Company, Syracuse, N. Y.

Polyphase Motors.—Bulletin, 4 pp. Describes the bearing and oil well construction of Century polyphase motors. Century Electric Company, St. Louis, Mo.

Speed Reducers.—Catalog, 25, 80 pp. Describes IXL speed reducers for stepping down electric motor speeds. Foote Bros. Gear & Machine Co., 215 No. Curtis Street, Chicago, Ill.

Non-Corrosive and Heat Resisting Steels.—Booklet, 24 pp. Describes Rezistal steels, including Atha's alloys; stainless steel and iron. Crucible Steel Company of America, 17 East 42nd Street, New York.

Receptacles and Cable Connectors.—Bulletin 53, 28 pp. Describes various types of receptacles, plugs and cable connectors for industrial plants and business buildings. Heavy duty types predominate. Russell & Stoll Company, 53 Rose Street, New York.

Electric Hoists.—Catalog, 60 pp. Describes a comprehensive line of floor operated electric hoists, illustrating installations, and including clearance drawing and dimensions, together with complete information regarding capacities, heights of lift, prices, etc. Shepard Electric Crane & Hoist Company, Montour Falls, N. Y.

Thrust Bearings.—Bulletin E, 12 pp. Describes Kingsbury thrust bearings, vertical adjustable types. Contains complete technical data and tables, and illustrates a 69-inch bearing with a capacity of 1,250,000 lbs. used in three of the 70,000 h. p. hydroelectric units recently installed by the Niagara Falls Power Company. Kingsbury Machine Works, Philadelphia, Pa.

Motor Valve Operator.—Bulletin J-12. A late development in the motor operation of industrial valves for high and low pressure steam, water and gas. Among the features of the new unit are a simplified positive acting limit switch; overload cutout; high torque; simple construction; steam, dust and water proof. The motor is disengaged when idle. Liberty Electric Corporation, Stamford, Conn.

Electrical Protective Devices.—Handbook 5005, 36 pp. Describes oil motor starters and switches, for small industrial apparatus, 750 volts or less, a-c. and d-c., including the new type N-4, arranged for thermal overload cutouts; also air circuit breakers. Condit Electrical Manufacturing Company, So. Boston, Mass.

Motion Pictures.—Booklet, 48 pp. Describes twenty-two motion picture films showing the growth and application of electricity in different industries, the manufacture of electrical apparatus, research and development, etc. The films listed in this booklet are loaned without charge for exhibition in the United States in the interest of commercial development, education and other purposes. General Electric Company, Schenectady, N. Y.

Ground Rods and Wire Data. Data Sheet. Describes Copperweld ground rods. Such rods are composed of steel core with a copper exterior permanently welded thereto, assuring high conductivity, rigidity and immunity to rust. Binders holding sheets thus far issued, together with index, covering engineering data on Copperweld and other wire for electrical uses, are also available. Copperweld Steel Company, Rankin, Pa.

Protective Relays.—Bulletin "Silent Sentinels," 72 pp. Describes protective relays for a-c. and d-c. systems. Over 140 illustrations, including schematic, vector and wiring diagrams, supplement the excellent descriptions of the theory and principles of operation of the relay. The results of many years of relay research by the Westinghouse Company are contained in this publication. Westinghouse Electric & Manufacturing Company, Newark Works, Newark, N. J.

NOTES OF THE INDUSTRY

Gibb Welding Machines Company, Bay City, Mich., manufacturers of electric welding and heating equipment announce a change in name from Gibb Instrument Company.

Kuhlman Electric Company, Bay City, Mich., has appointed the Globe Electric Supply Company, 1843 Wazee Street, Denver, Colorado, as district representatives for the states of Wyoming, Colorado and New Mexico.

Howard J. Wittman, 632 Nasby Building, Toledo, Ohio, has been appointed district representative, with northwestern Ohio as his territory.

Allis-Chalmers Mfg. Company Milwaukee, Wis., has added to the line of Type "S" centrifugal pumps, a new low head pump built in the smaller sizes, similar to the other Type "S" equipment, except that there are incorporated a number of mechanical improvements, and a higher efficiency is obtained due to elimination of a number of hydraulic losses.

The Sangamo Electric Company, Springfield, Ill., has recently developed a three-element, three-phase meter for accurate metering on four-wire, three-phase circuits where both unbalanced voltages and currents are likely to exist. In addition to eliminating the need for three single-phase meters, the three-element meter is particularly useful where it is desired to obtain demand readings for which purpose the use of three single-phase meters is unsatisfactory.

Steinmetz Memorial Fund.—The General Electric Company has appropriated $25,000 as a Steinmetz Memorial Fund for Union College in memory of Dr. Charles P. Steinmetz. The income from this fund will be used to provide four scholarships annually. Students in any of the courses at Union are eligible, but preference will first be given to sons of employees of the General Electric Company and second to sons of residents of Schenectady, N. Y.

Underwriter's Laboratories, New York, has announced to manufacturers of rubber covered wires subscribing to the Label Service, that effective January 1, 1925, the further use of labels on newly manufactured product in sizes No. 8 B. & S. gage and smaller will be restricted to wires having braids woven to meet a specification recently adopted. This specification makes available for the first time means for classifying braids as to closeness of weave and covering capacity. Its general intent is to insure that the surface of the rubber insulation is well covered where wires are twisted or bent as well as when lying straight.

Experimental 110,000 Volt Underground Cable.—Supplementing laboratory and factory tests on high voltage cable, a field test on a commercial length operating at 110,000 volts is being made by the General Electric Company. For this field test a 200-foot length of single conductor cable is connected to the system of the Adirondack Power and Light Corporation at its North Albany station, Albany, N. Y. The cable is connected through a separate oil switch outside of the lightning arresters, and is therefore subject to all of the surges, overvoltage stresses, etc., which might occur in the system proper. Up to this time the length has been under test for more than five weeks and no trouble has developed. This is said to be the highest voltage at which a lead sheathed cable has been operated in this country. The nearest approach is the 66,000 volt cable used by the Cleveland Electric Illuminating Company.


KERITE INSULATED WIRE & CABLE CO
DAYS KERITE
KERITE
in a half-century
of *continuous*
production,
has spun out
a record
of performance
that is
unequalled
in the history
of
insulated wires
and cables.
KERITE INSULATED WIRE & CABLE COMPANY
NEW YORK
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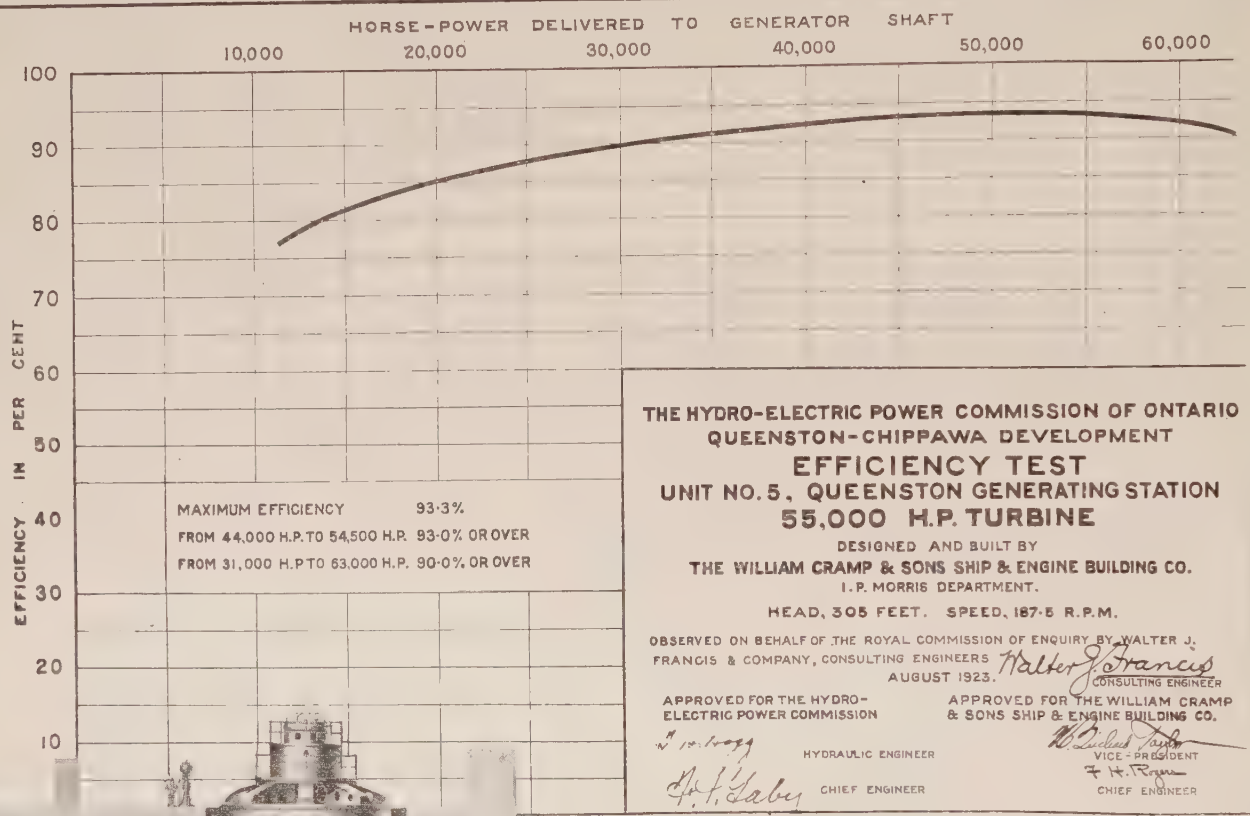
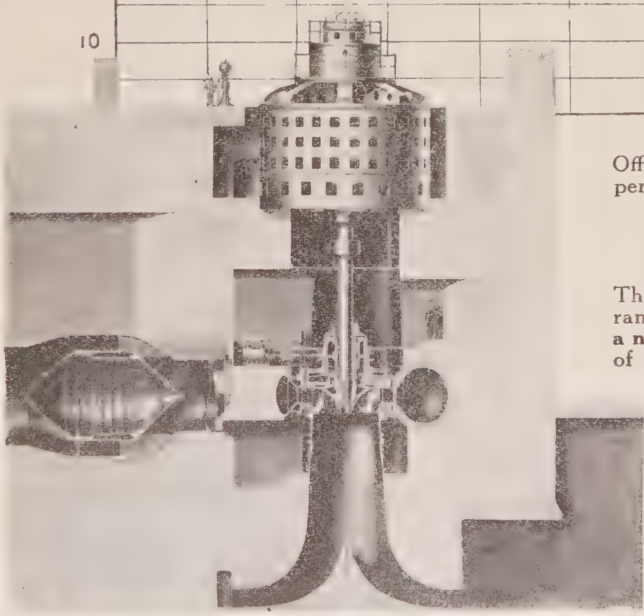
I. P. Morris Hydraulic Turbines

The Wm. Cramp & Sons Ship & Engine Building Co.

Richmond and Norris Sts., Philadelphia

New York Office: 100 Broadway **Birmingham Office: American Trust Building**





Official test shown above resulted in the following remarkable performance

Maximum Efficiency	**93.3%**
From 44,000 H. P. to 54,500 H. P.	93.0% or over
From 31,000 H. P. to 63,000 H. P.	90% or over

The extremely high efficiency secured throughout the wide range in power, is a noteworthy achievement and sets **a new record in hydroelectric engineering.** The performance of this turbine proves the value of **the careful engineering study of each detail of design,** the adoption of many special features of design, which have been developed and perfected in the testing laboratory, and the extreme care taken in the shops. Some of the most noteworthy features used with this unit are:—

Turbine Runner and Volute Casing of Improved Design
Moody Spreading Draft Tube
Disk Guide Vanes
Labyrinth Runner Seals

Designers and builders of the Johnson Hydraulic Valve and the Moody Spiral Pump.

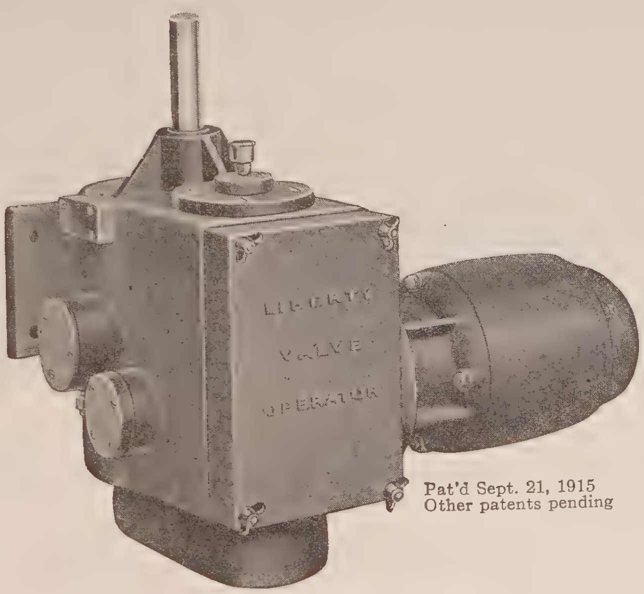
ASSOCIATED COMPANIES

The Pelton Water Wheel Co., San Francisco and New York
Dominion Engineering Works, Ltd., Montreal, Canadian Licensees
M. Hilpert & Co., Rio de Janeiro, Brazilian Licensees

LIBERTY ELECTRIC CORPORATION STAMFORD CONN U. S. A.
TRADE MARK

Announcing
the
LIBERTY VALVE OPERATOR

for high and low pressure steam, water and gas valves



Pat'd Sept. 21, 1915
Other patents pending

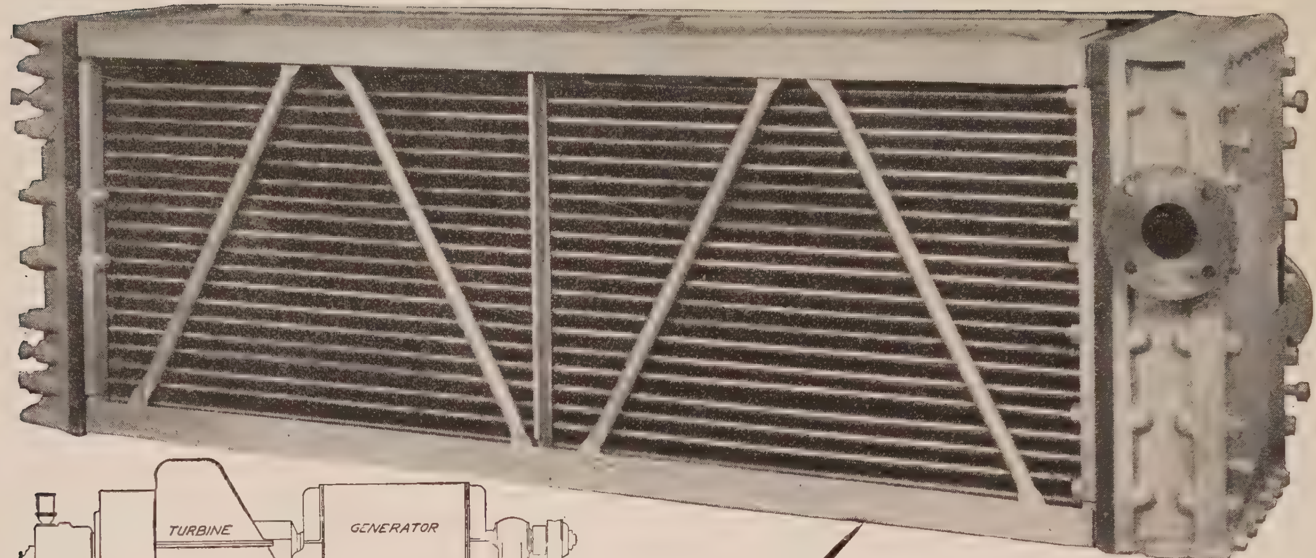
The Liberty Valve Operator represents the latest development in motor operation of industrial valves. Below are some of the more prominent features of the new Liberty units.

1—Simplified positive acting limit switch
2—Overload cutout
3—High torque
4—Simple accessible construction
5—Motor disengaged when idle
6—Steam, dust and water proof
7—Fewer parts and those of sturdy, dependable design.

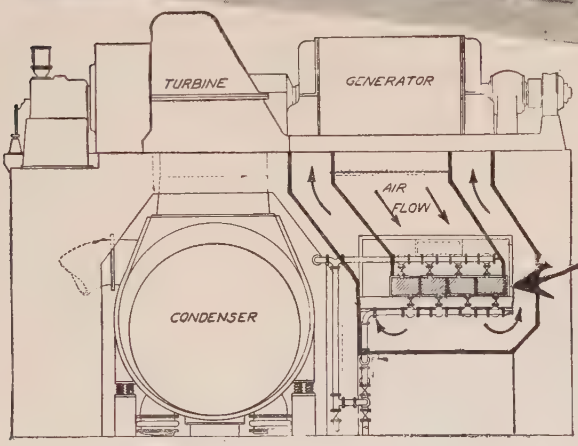
See the new Liberty unit in operation—Booth No. 4, Pittsburgh Valve, Foundry & Construction Company, National Exposition of Power and Mechanical Engineering, Grand Central Palace, New York City, December 1st to 6th.

Write for descriptive circular J-12

LIBERTY ELECTRIC CORPORATION
STAMFORD, CONN.



A section of the G-E Surface Air Cooler



Advantages

Use the closed system of ventilation and profit by these advantages

Generator protection—the closed system of ventilation using only clean, dry air.

Less fire hazard—because the volume of air in this system can support but little combustion.

Compactness—requiring a minimum amount of duct work.

Fuel economy—by heating turbine condensate with the generator losses and returning this heat to the boiler.

The cooler can be paralleled with the condenser circulating system—giving a reliable and inexpensive water supply, without the need for an additional pump.

A minimum volume of water is required—of value where water supply is limited.

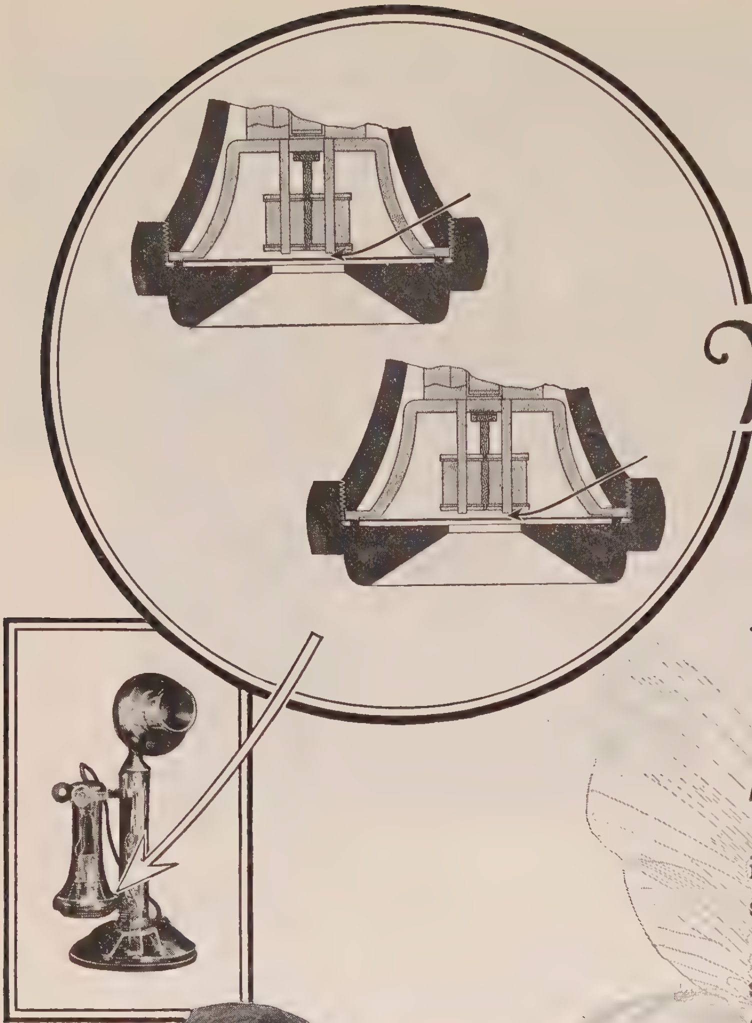
Salt water can be used for cooling—a convenience in many cases.

The General Electric generating equipment going into modern plants today includes Air Coolers for their closed system of generator ventilation. More than a million kw. have been installed. Write for further information.

31-52

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., SALES OFFICES IN ALL LARGE CITIES



Which space is bigger?

by the thickness of a bee's wings

THE picture shows the ends of two telephone receiver magnets. The spaces indicated by the black arrows are equal in size—to the unaided eye.

But the extremely fine measuring instruments which Western Electric uses, show one space to be wider than the other by the thickness of a bee's wings. Even so small a difference is too great to pass the rigid inspection which watches over the making of your telephone.

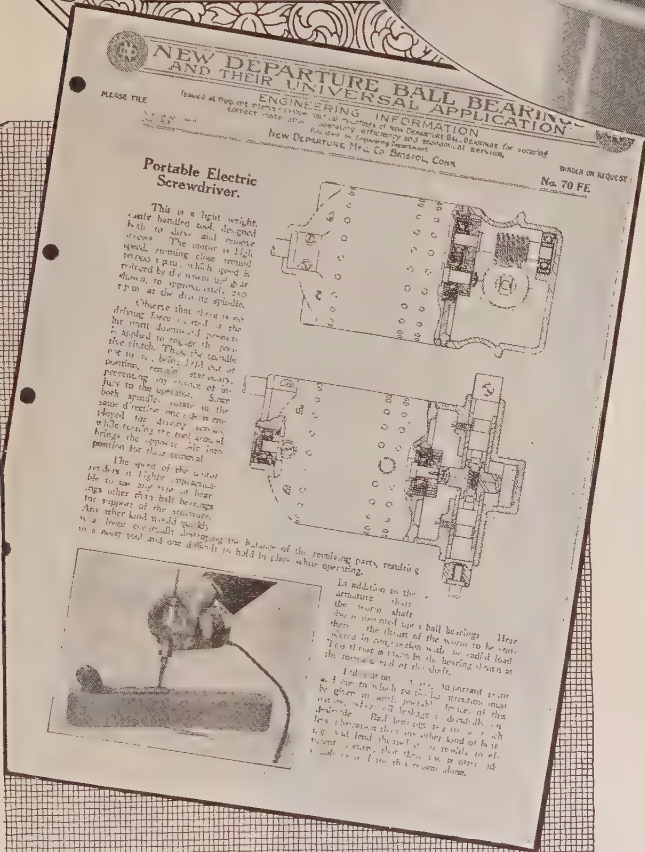
This care for detail is one reason why your telephone is so dependable. It is typical of the whole work of producing Western Electric equipment, and is a manufacturing habit which dates back to the very beginning of telephone history.

Under the receiver cap is a thin disc of iron. For proper voice reception, the distance between disc and magnet must be fixed with minute accuracy. The operative shown here, by grinding the magnet unit, makes this distance just right.

Western Electric

SINCE 1869 MAKERS OF ELECTRICAL EQUIPMENT

New Departure Ball Bearings



NEW DEPARTURE BALL BEARINGS AND THEIR UNIVERSAL APPLICATION

ENGINEERING INFORMATION

NEW DEPARTURE MFG. CO. BRISTOL, CONN.

No. 70 FE

Portable Electric Screwdriver.

This Engineering Data Book is

more than a catalog
more than an application book
more than a text book
more than load data

It is all of these things combined—truly a reference work on ball bearings for the use of the engineer, chief draftsman or designer.

—Never grows old, out of date or obsolete.

—Is accepted as authoritative and used by thousands of technical men, 3,000 of whom look forward to the new data received each month. In requesting please use your Company letter-head, and indicate official position.

Portable Electric Screw Driver

An interesting installation of New Departures. The speed of this motor makes it highly impracticable to use a sleeve bearing which would quickly wear loose eventually destroying the balance of revolving parts, resulting in a noisy tool and one difficult to hold in place.

The New Departure Mfg. Co.

Detroit **Bristol, Conn** **Chicago**

58

TEN YEARS without a single essential change and the demand growing by leaps and bounds — that is the record of the Sangamo Type-H Alternating-current Watthour Meter.

Parts made today fit perfectly in meters bought ten years ago.

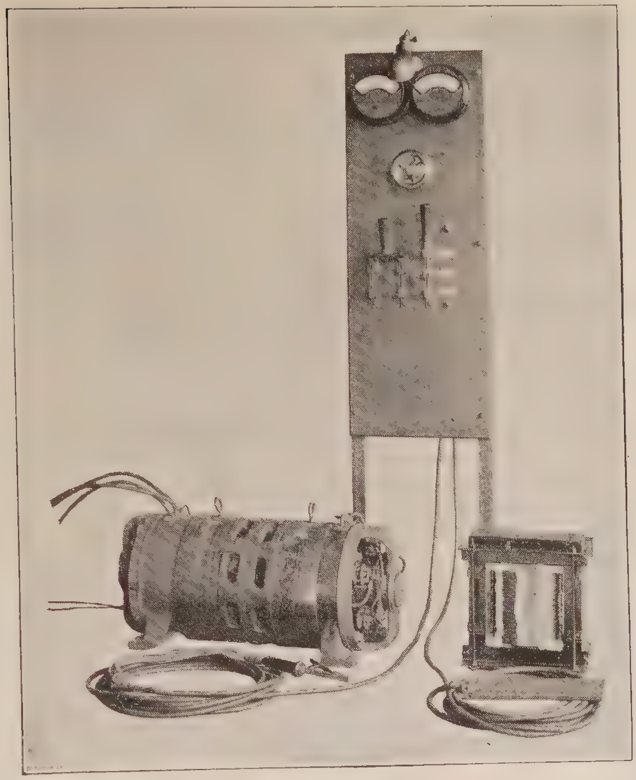
SANGAMO ELECTRIC COMPANY

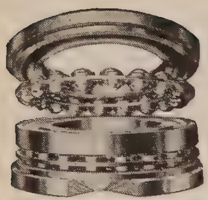
Springfield, Illinois

New York Chicago Birmingham San Francisco Los Angeles

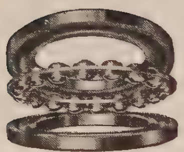
METERS FOR EVERY ELECTRICAL NEED

6420-1



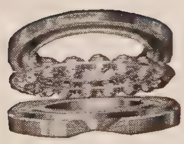


Double-acting thrust bearing, flat seats (grooved races) 2100-F Series



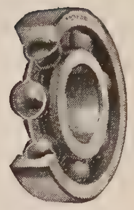
Single-acting thrust bearing, flat seats (grooved races) 1100-F Series

Single-acting, self-aligning thrust bearing 1100 Series

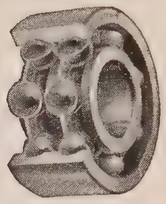


Single-acting, self-aligning thrust bearing, leveling washer. 1100-U Series

Double-acting, self-aligning thrust bearing, leveling washers 2100-U Series



Single-row deep-groove Standard type, radial bearing



Double-row, deep-groove Standard type, radial bearing

Angular contact bearing, combination radial and thrust

Double-row, maximum type, radial bearing

Single-row, maximum type, radial bearing

Motor manufacturers are getting in line

Strom Ball Bearing Equipped Motors have many advantages

The principal advantages are:

1—A permanent and uniform air gap between armature and coils.
2—Elimination of oil leakage. This prevents insulation troubles.
3—Starting and running resistance minimized and equalized.
4—More compact motor design due to small bearing space required.
5—End motion of rotor and vibration reduced to a minimum.

Add to these five points of superiority a marked reduction in cost of maintenance and service, and higher efficiency of the motor, and you have the principal reasons why Strom Ball Bearings are used.

Write to us for further information, catalog and price list. Our engineers will gladly assist you if you will send them your bearing problems. Write.

Strom BALL BEARINGS

STROM BALL BEARING MFG. CO.
Formerly U. S. Ball Bearing Mfg. Co.
4595 Palmer Street, Chicago, Ill.

The Steel-Clad

SK Distribution Transformer

Group of Steel-Clad Type SK Transformers

The advantages that have been secured in the new line of Westinghouse Steel-Clad Type SK Transformers are as follows:

Mechanical:

Improved appearance.
Light weight.
More sturdy construction.
Freedom from breakdown inherent in cast iron.

Electrical:

Reduced iron and copper losses.
Higher efficiency.
Improved regulation.
Improved coil insulation.
Stronger high-voltage bushings.
(High-flash-over voltage maintained by petticoat construction.)
Heavier high-voltage leads.

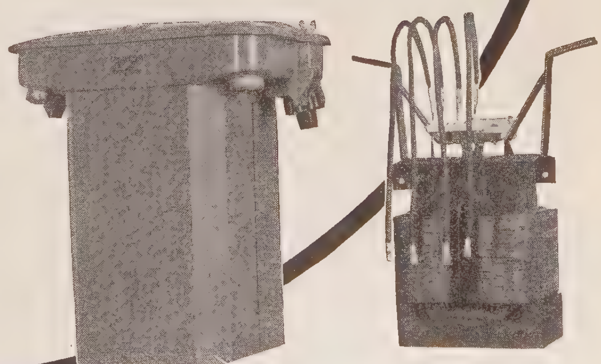
The unqualified and thoroughly demonstrated success of Westinghouse Steel-Clad Distribution Transformers, placed on the market in 1919, has led the Westinghouse Company to extend this type of construction to the higher-voltage distribution transformers.

Announcement is therefore made of a new line of steel-clad distribution transformers for voltages of 6900, 11,500 and 13,800.

Descriptive Leaflet 20133 gives full particulars.

Westinghouse Electric & Manufacturing Company
East Pittsburgh Pennsylvania
Sales Offices in All Principal Cities of the United States and Foreign Countries

WESTINGHOUSE ELECTRIC



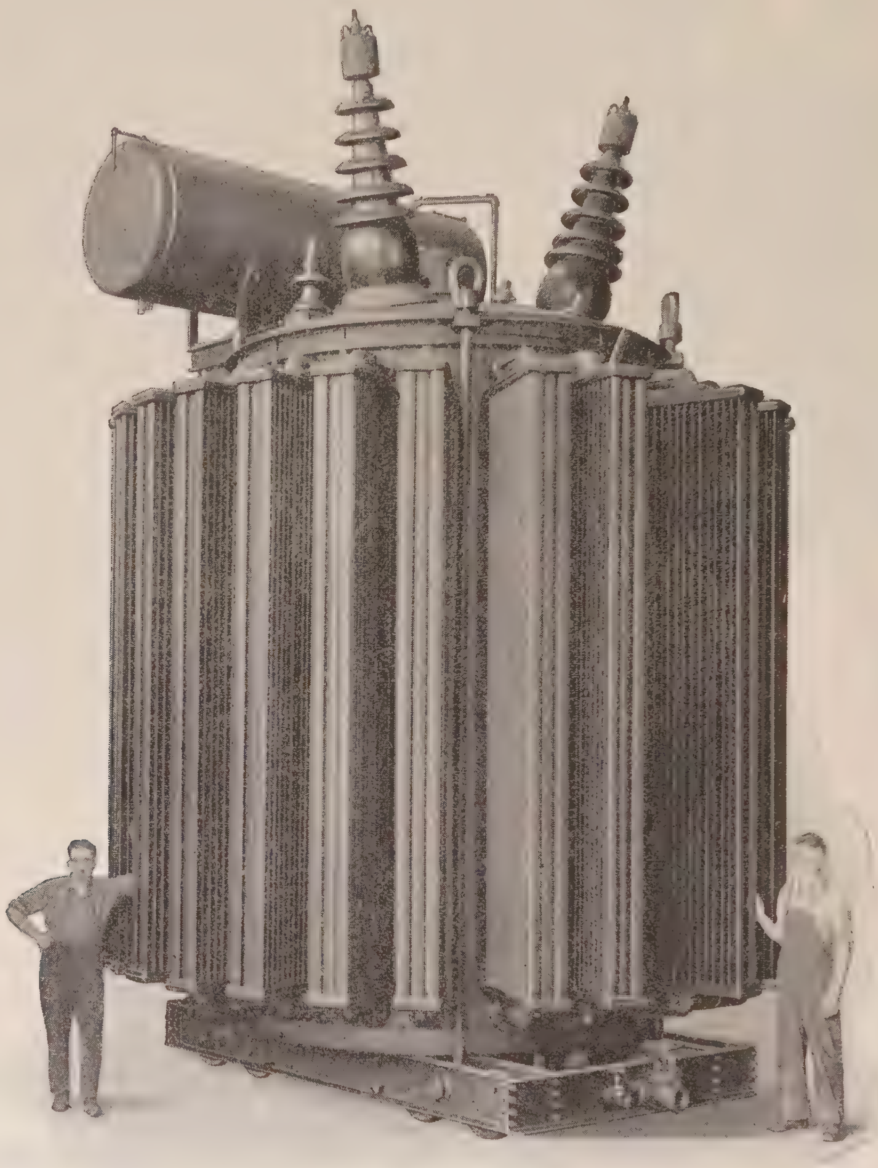
15-Kv-a, 6900-Volt, Steel-Clad, Type SK Transformer

Westinghouse

22 Mammoth Power Transformers

for Public Service Electric and Gas Co. of New Jersey

Rated 15,000 KV-A. each, these are among the largest high-voltage, self-cooled transformers ever built.



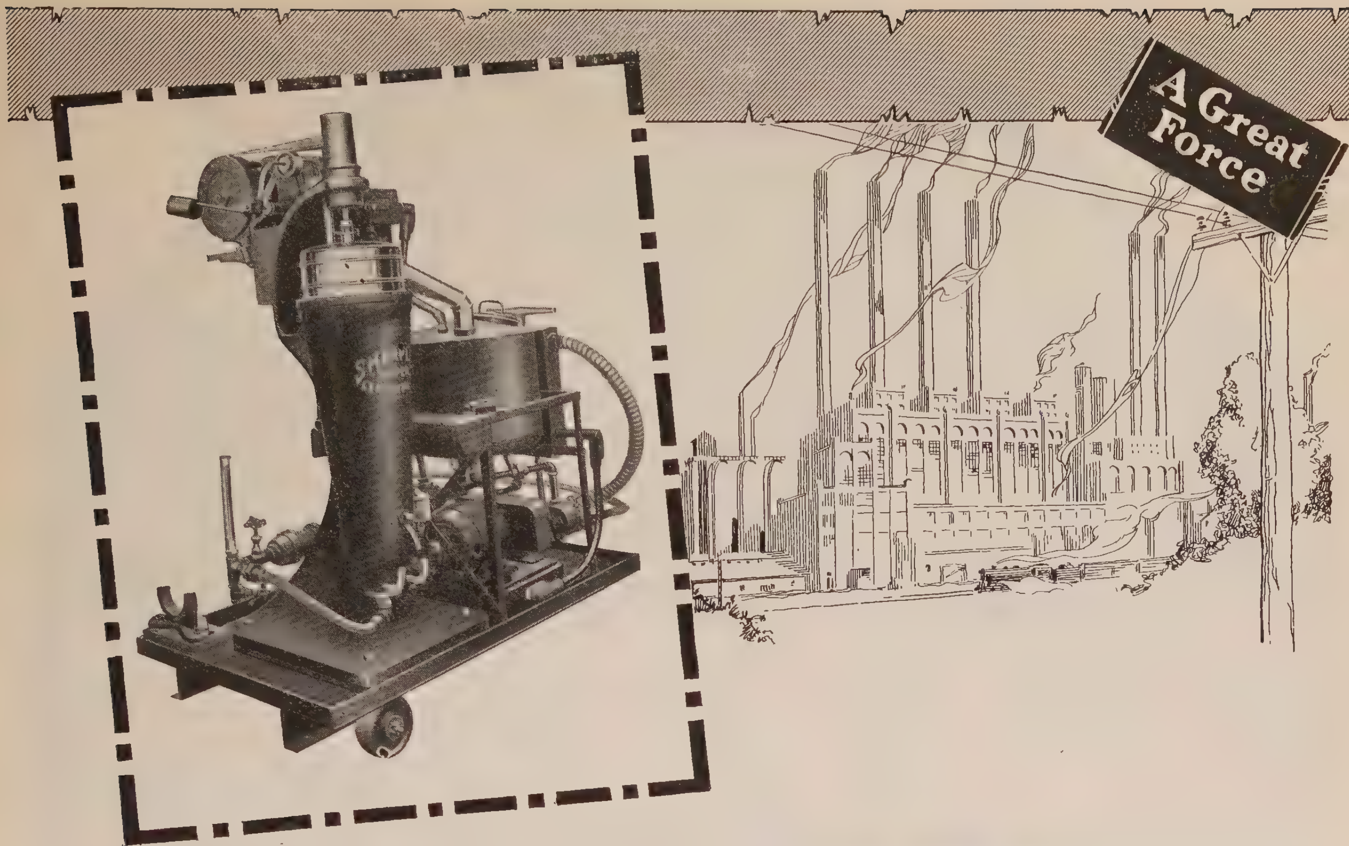
15,000 KV-A., 132,000 Volts, 60 Cycle, Single Phase, Oil-insulated, Self-cooled Transformers.

The Public Service Gas & Electric Company of New Jersey, for whom twenty-two of these large transformers are being completed, will have installed by the Public Service Production Company nearly half a million KV-A in Allis-Chalmers power transformers.

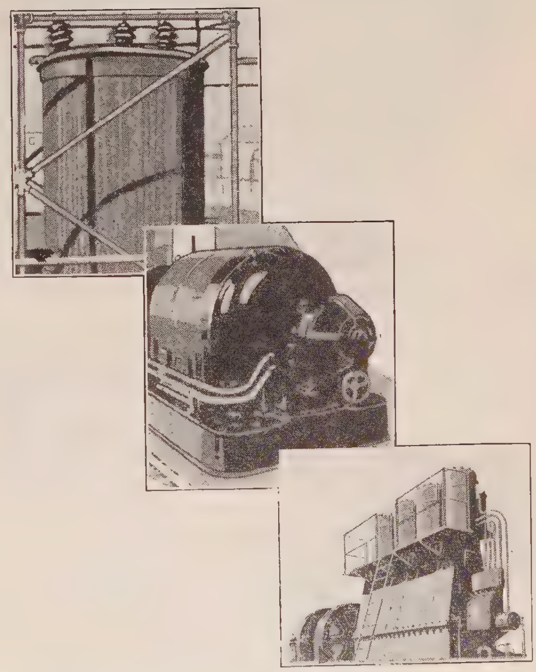
**Bulletin No. 1108-A shows many of these installations
Send for your copy.**

ALLIS-CHALMERS

MILWAUKEE, WIS. U. S. A.



The Electrical Industries and Sharples Super Centrifugal Force



Leading electrical engineers and power plant experts everywhere have recognized the value of Sharples Super Centrifugal Force in clarifying and reconditioning insulating and lubricating oils. Electrical plants and power houses point to their Sharples Super Centrifuge installations as a determining factor in the efficient and consistently dependable performance of their Transformers, Turbines or Diesel Engines.

* * *

High dielectric strength is absolutely essential in transformer oils. The Sharples Portable Super Centrifuge plays an important part in this connection. The oil is treated in the Sharples by the action of the most powerful centrifugal force ever commercially applied. All moisture and suspended impurities are rapidly eliminated and the dielectric strength is restored.

The machine is readily moved to any desired position and can be stopped, cleaned and reassembled by one man in fifteen minutes.

The Sharples Specialty Company
2300-2324 Westmoreland Street
Philadelphia

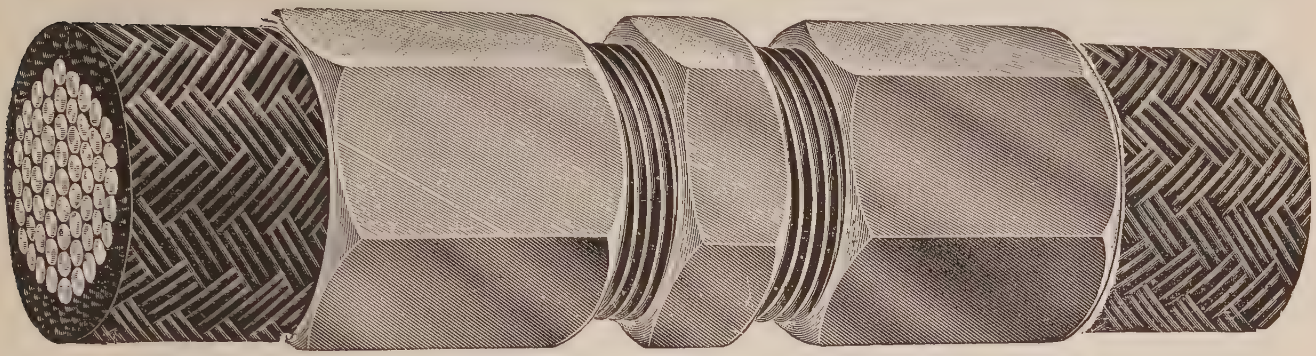
Representatives in all principal industrial territories

The Sharples Portable Super Centrifuge is equally as valuable for purifying lubricating oils used for Diesels and Turbines. Its effective removal of all foreign matter keeps the oil constantly in condition to preserve the bearings, lower their upkeep, and effect economy in lubrication.

SHARPLES Portable Super Centrifuge

This is the First Device Approved by National Board of Fire Underwriters

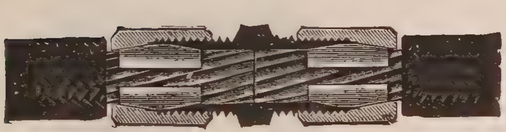
for making connections without the use of solder.



DOSSERT

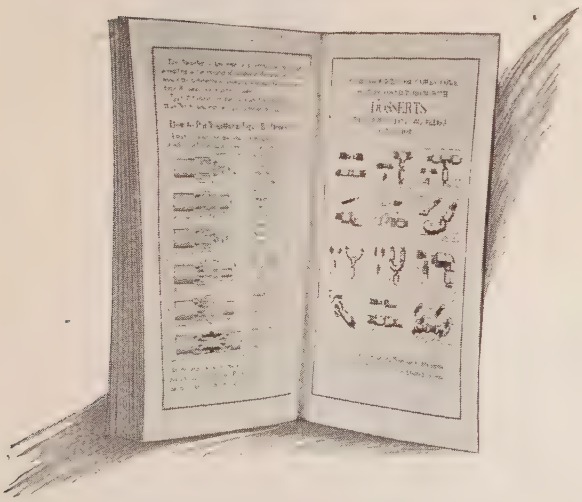
Originated in 1904

Principle



2-Way, Type A, Showing Details

The whole effectiveness of a Dossert Joint hinges on the TAPERED SLEEVE principle. This principle has been adhered to continuously.



Uses

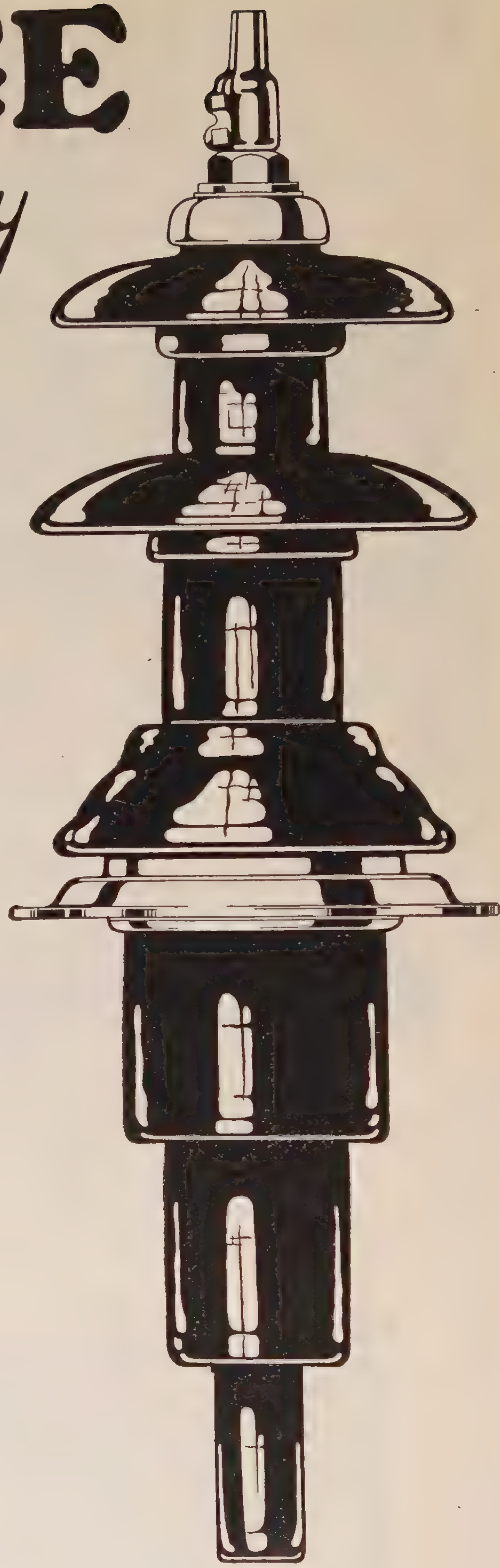
With Dossert Devices any combination of different sizes of cables, stranded and solid wires, rods and tubing can be connected together. The cable tap will tap from any size main to any size branch. Terminal and switchboard lugs, front or back connected; angle and swivel lugs, insulated connectors; two-ways, three-ways, equalizers, cable anchors, reducers, elbows, Y's, service box lugs and plugs, grounding devices and stud connectors for threaded rods and flat strips or blocks made in every necessary size and form for all conceivable connections ranging from No. 14 to 2,500,000 C.M. conductors

The Line Today

The acceptance by engineers of the Tapered Sleeve principle has led to its adoption for innumerable services indoor and outdoor—so that in publishing the 1924 issue of the Dossert Catalog and Data Book 64 pages were required properly to present the subject.

DOSSERT & COMPANY

H. B. Logan, *President* **242 West 41st Street, New York City**



STURDY fighting men of old fought clad in steel armor from head to foot and so—are the CONDIT types F-8 and F-9 armored with steel from top casting to cradle—to withstand battles encountered in service.

Steel—top, tank, cradle—wherever steel is best steel is used, providing maximum mechanical strength.

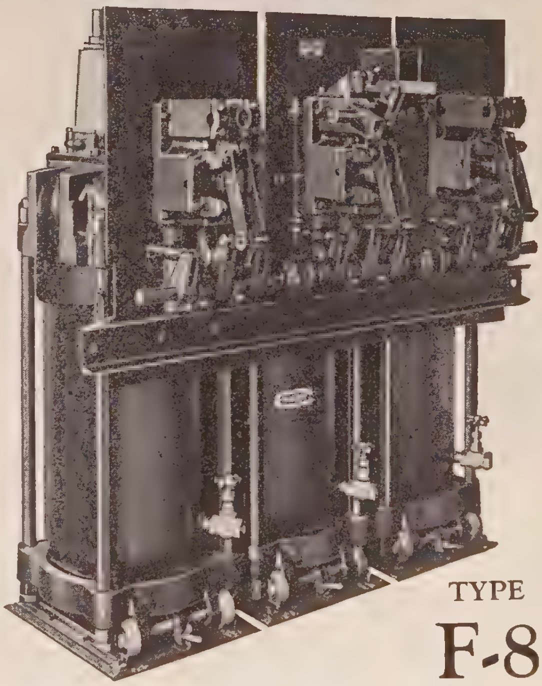
This coupled with four series breaks per pole affords high interrupting capacity and a high factor of safety. Truck type—units mechanically interlocked, or if you prefer platen mounted.

They're built for service and they give it.

"Get in touch with Condit"

CONDIT ELECTRICAL MFG. CO.
Manufacturers of Electrical Protective Devices
South Boston, Mass.

Northern Electric Company LIMITED
Sole Distributor for the Dominion of Canada

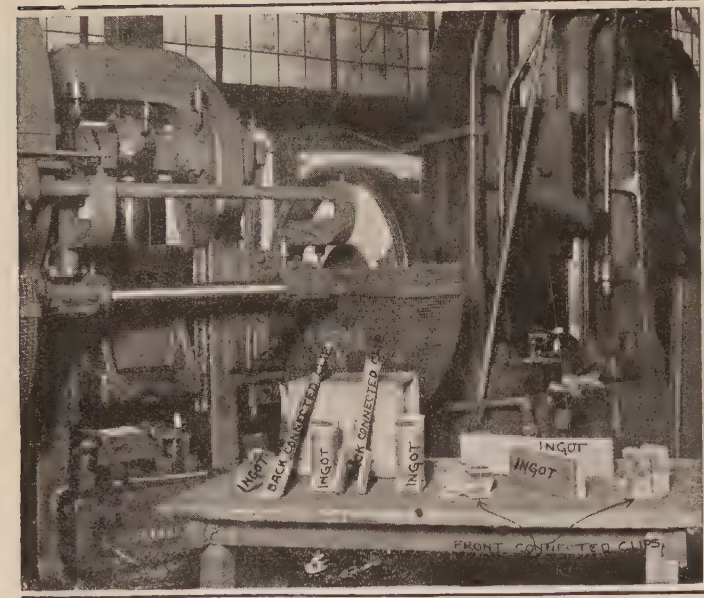


TYPE
F-8

Specifications: Standard capacities for 15,000 or 25,000 volt service. Interrupting capacity: F-8, 18,000 amperes at 15,000 volts; F-9, 30,000 amperes at 15,000 volts.

7410

CONDIT



Showing how Champion disconnecting switch clips are drop-forged from solid, one-piece pure copper ingots.

Champion One-Piece Drop-Forged Disconnecting Switch Clips

All Champion disconnecting switch clips are *drop-forged* from a solid, one-piece pure copper ingot.

We call your attention to this fact and emphasize it for reasons obviously important to you.

It means a high conductivity of 98½ per cent, according to Matthiessens standard.

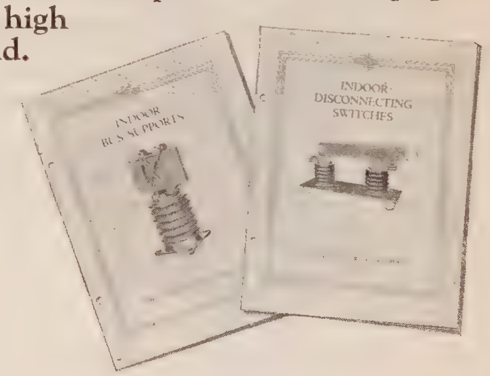
It produces a much stronger, more rigid unit than castings, while the conductivity of the latter type is only from 70 to 75 per cent and in many cases even less than that.

This is only one of many important Champion characteristics that hold down the cost of maintenance and assure a greater dependability of service. It is a valuable contribution we are happy to have made to the improvement of equipment in the high tension field.

Announcing Two New Bulletins

Bulletin B, covering complete information, including drawings, all dimensions and other details, on Champion Bus Supports and Bulletin C, covering Champion Indoor Disconnecting Switches, are now ready for distribution.

Write us for copies so you can keep this valuable information on file for ready reference.



SALES REPRESENTATIVES

Garland Affolter Engineering Company
Rialto Building San Francisco, California
Garland Affolter Engineering Company
I. W. Hellman Building Los Angeles, California
Garland Affolter Engineering Company
Alaska Building Seattle, Washington

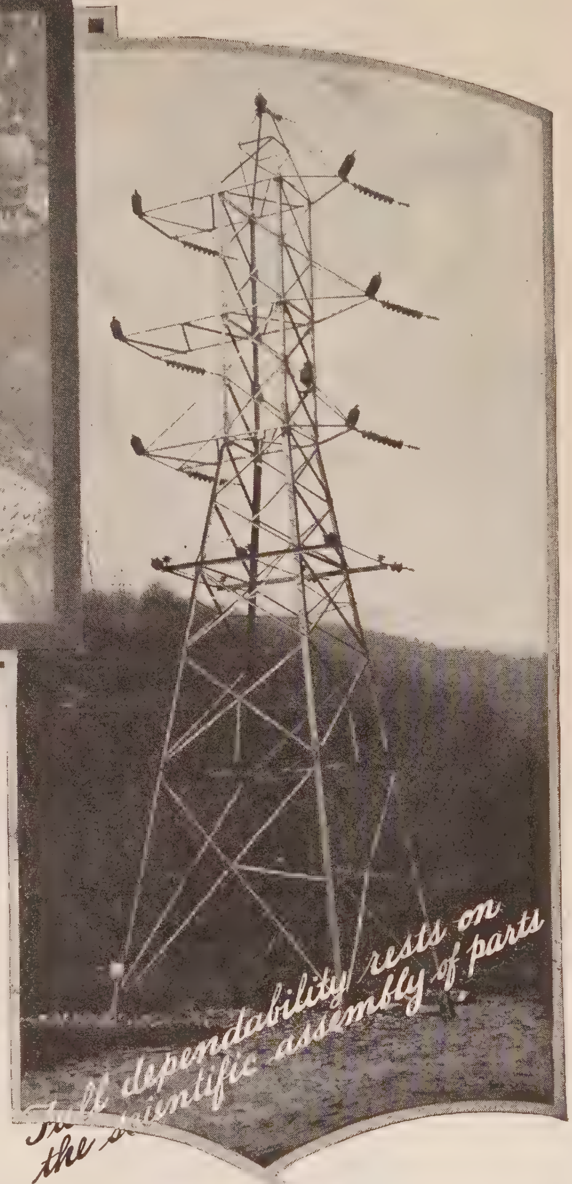
Champion Switch Company
Rooms 510-512 2 Rector St. New York City
Champion Switch Company
924 Marquette Building Chicago, Illinois
Champion Switch Company
413 Glenn Building Atlanta, Georgia

A. H. Savage & Company
914 Pioneer Building St. Paul, Minnesota
Mr. Ralph D. Ernest
205 Kresge Building Detroit, Michigan
Mr. T. W. McCabe
Winnipeg, Canada

THE CHAMPION SWITCH COMPANY—550 ABBOTT ROAD—Post Office Box 816—Buffalo, N. Y.

The CHAMPION SWITCH COMPANY

Locke Insulators are Sure of Themselves



THE workman who flirts with death on the pinnacle of the Woolworth tower by trusting his hold to the reliability of steel supports, is merely dealing with *known factors of security*.

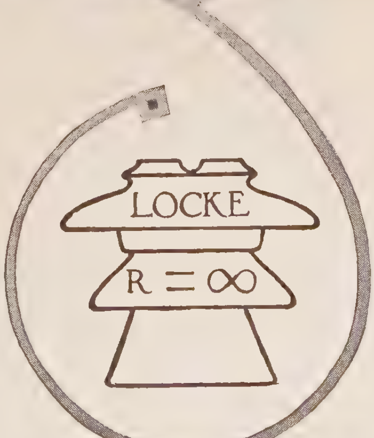
But the most essential factor is confidence in himself. He is not so much performing a "stunt" as he is emphasizing the exact co-ordination of mind, muscle and material upon which depend his safety in the daily task.

The inter-dependence of metal parts with porcelain units in strings, bears a close analogy to the above illustration. From the line suspension clamp (upon which the "foot of the insulator" rests) to the hook or other connecting device with the steel tower, each piece of hardware and porcelain must perform its function dependably. Contraction and expansion, without injury to the porcelain, must be provided for in the design and assembly of materials.

In all these particulars Locke Insulators are the products of skilled co-ordination of inter-related parts—an accomplishment which is realized only through many years of specialized experience.

Locke Insulators can be relied upon at all times—however hazardous the situations they meet in the daily performance of duty.

LOCKE INSULATOR CORPORATION
Baltimore, Md., and Victor, N. Y.

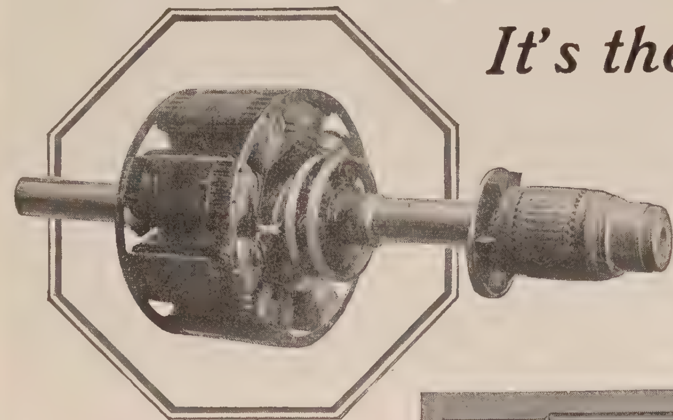


LOCKE
PORCELAIN

ROCKBESTOS

—the asbestos covered wire.

It's the Insulation!



Field coils of Allis-Chalmers small Synchronous Motor wound with Rockbestos

Rockbestos insulation will not break down under the severest use. It is extremely tough and will not break nor crack when bent.

Made in round, square, or rectangular shape to your specifications.

Samples and prices on request.

Rectangular magnet wire

ROCKBESTOS PRODUCTS
CORPORATION
NEW HAVEN CONN.

New York Sales Offices: 5942 Grand Central Terminal Bldg. Western Branch Office: 711 First National Bank Bldg., Chicago, Ill.

Hazard
RUBBER INSULATED
WIRES & CABLES

SpiralweavE

HAZARD SPIRALWEAVE CABLE is a ruggedly built "Firehose" type Cable for the hardest kind of work. The rubber insulation is the highest quality; the protective covering consists of a rubber faced cloth tape and an extra heavy *woven* (not "braided") fabric,—tough, strong, wear-resisting and thoroughly weatherproof.

A trouble-proof electrical cable for mines, railroad work, or wherever a strong, long-wearing cable is needed.

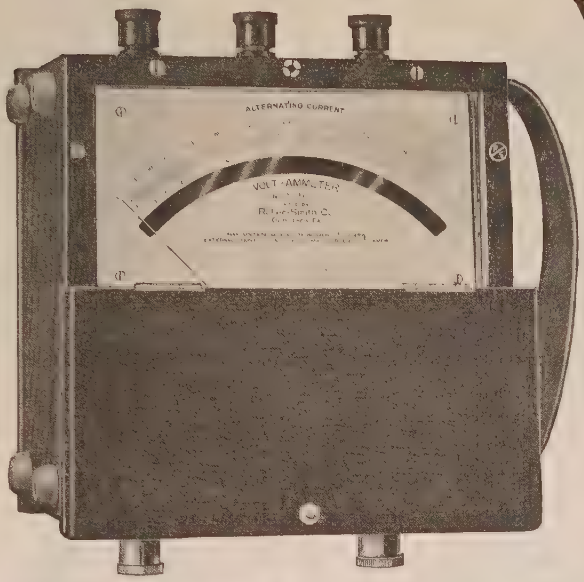
"Made for Users Who Want the Best"

HAZARD MFG CO WILKES-BARRE PA

NEW YORK, CHICAGO, PITTSBURGH, DENVER, BIRMINGHAM

AT LAST! An Alternating-Current Combination Volt-Ammeter

Roller-Smith takes particular pride in presenting its latest contribution to the instrument art — *a combination volt-ammeter for alternating current.* Convenient size, light weight, rugged and — *above all* — accurate and reliable.



The Type GSA Volt-ammeter and other Type GSA instruments are fully described and listed in Bulletin AE-160. Your copy is ready for you. Send for it.

ROLLER-SMITH COMPANY

Electrical Instruments, Meters and Circuit Breakers

MAIN OFFICE: 12 Park Place, NEW YORK

WORKS: Bethlehem, PENNA.

BALTIMORE, 113 E. Franklin St.
BIRMINGHAM, Brown-Marx Bldg.
BOSTON, 141 Milk St.
BUFFALO, Ellicott Square
CHICAGO, 430 So. Green St.
CLEVELAND, 7016 Euclid Ave.
DALLAS, 2002½ Live Oak St.
DENVER, U. S. Nat'l Bank Bldg.
DETROIT, Ford Bldg.
LOS ANGELES, Consolidated Bldg.
MEMPHIS, 493 S. Main St.
MONTREAL, Power Bldg.
NEW ORLEANS, Whitney Central Bldg.
PHILADELPHIA, Otis Bldg.
PITTSBURGH, Keenan Bldg.
SCRANTON, 939 Capouse Ave.
SEATTLE, Hinckley Bldg.
SALT LAKE CITY, Dooly Bldg.
SAN FRANCISCO, 589 Howard St.
ST. LOUIS, Railway Exchange Bldg.
ST. PAUL, Pioneer Bldg.
TORONTO, 183 George St.
WASHINGTON, Evening Star Bldg.
Abroad: Thrall Electric Co., Presidente Zayas, No. 27, Havana, Cuba

Accuracy
in long continued service

TRADE MARK
BRISTOL'S
REG. U. S. PAT. OFFICE

Recording Voltmeters

There are no delicate or complicated parts to break or get out of order.

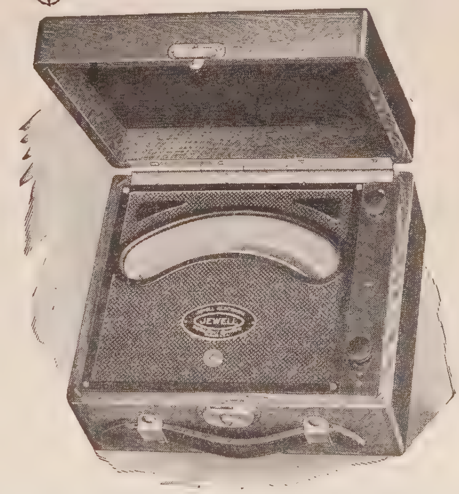
Thousands of Bristol's Recording Voltmeters, Ammeters and Wattmeters are proving of especial value to power plant operators and engineers, because they give information of paramount importance.

Where shall we send your copy of Catalog BC-1501?

THE BRISTOL COMPANY
Waterbury, Conn.

Branch Offices:
Boston, New York, Detroit, Pittsburgh, Philadelphia, Chicago, St. Louis, San Francisco

JEWELL

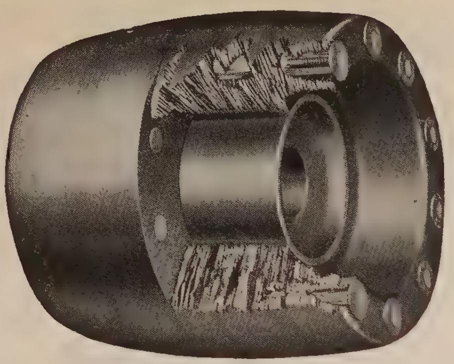


JEWELL PORTABLE NO. 2

Whether for switchboard mounting or for laboratory or portable testing, Jewell instruments have gained the recognition of Electrical Engineers throughout the country.

We shall be glad to submit instruments for competitive tests and comparisons.

Jewell Electrical Instrument Co.
1650 Walnut St. - Chicago



[Section removed to show construction]

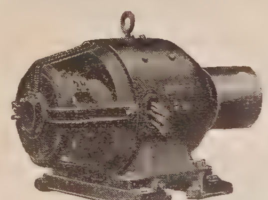
ROCKWOOD PAPER PULLEYS

1. Reduce slippage
2. Decrease belt tension
3. Transmit more power
4. Lower total cost of drive, due to narrower belts.

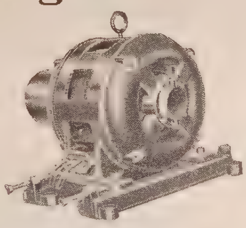
Whenever you buy a pulley for a motor, get a Rockwood Paper Pulley, the pulley that most every motor is equipped with when it leaves the factory. Rockwood is more than a pulley—*it is pulley service!* Order from your electrical dealer or direct from us.

THE ROCKWOOD MFG. COMPANY
1947 English Avenue INDIANAPOLIS, U.S.A.

Star Ball Bearing Motors



For Hard Usage — A. C. and D. C.



Complete line of standard motors and generators, all sizes up to 75 h.p. and 50 kw. respectively.
Our Engineering Department at your service for all special applications.

STAR ELECTRIC MOTOR CO.
NEWARK, NEW JERSEY

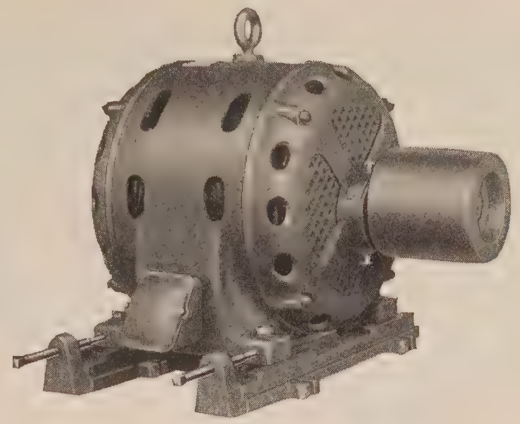
"IRVINGTON" PRODUCTS

Black and Yellow

Varnished Cambric Varnished Paper
Varnished Silk
Flexible Varnished Tubing
Insulating Varnishes and Compounds
"Cellulak" Tubes and Sheets

IRVINGTON VARNISH & INSULATOR CO.
Irvington, New Jersey.

Sales Representatives in all principal cities



The 30 H. P. Motor

Century

Squirrel Cage Induction

Polyphase Motor

bearings are built of the best grade cast phosphor bronze and are of a size to give years of uninterrupted service. To further insure a long life to the bearings, the bearing housings and oil wells are made as near dust proof as it is possible to build.

Write for Folder No. 535.

1/6 to 75 H. P.

Century Electric Company
General Offices; 1827 Pine Street
St. Louis, Mo., U. S. A.

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What would you give to avoid tuberculosis?

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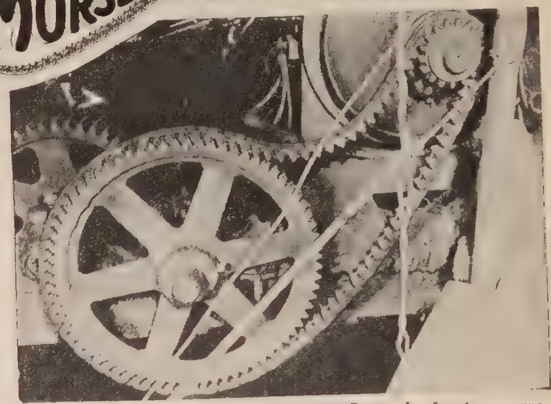

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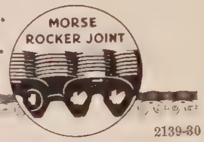

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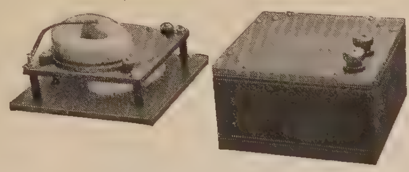

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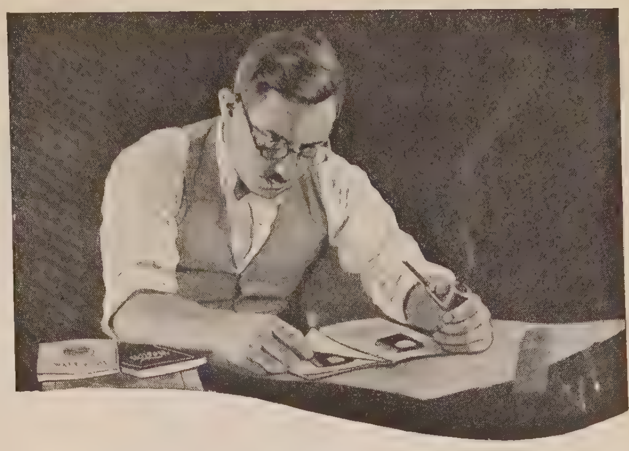

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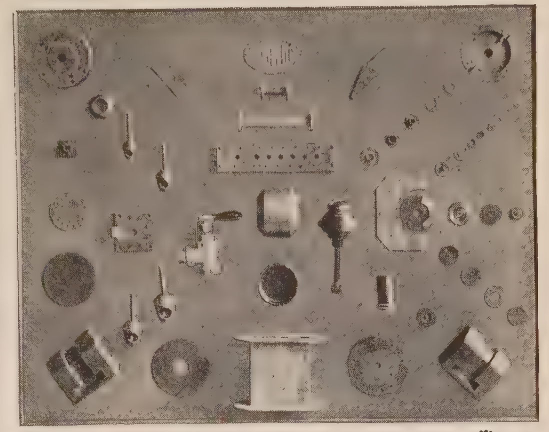

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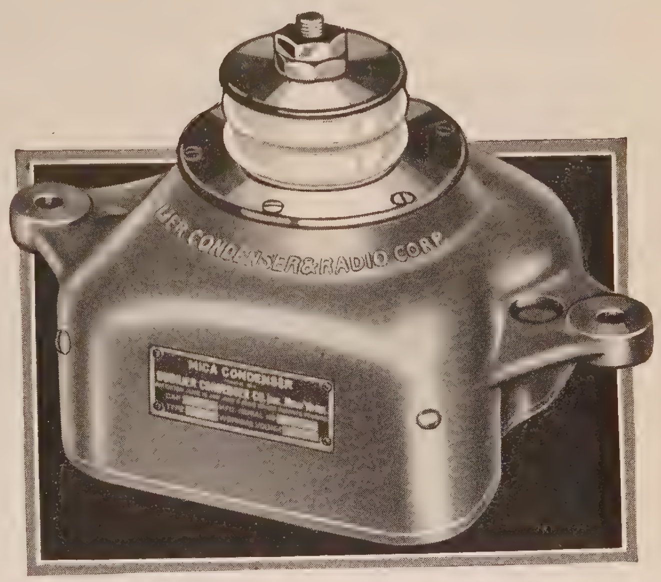

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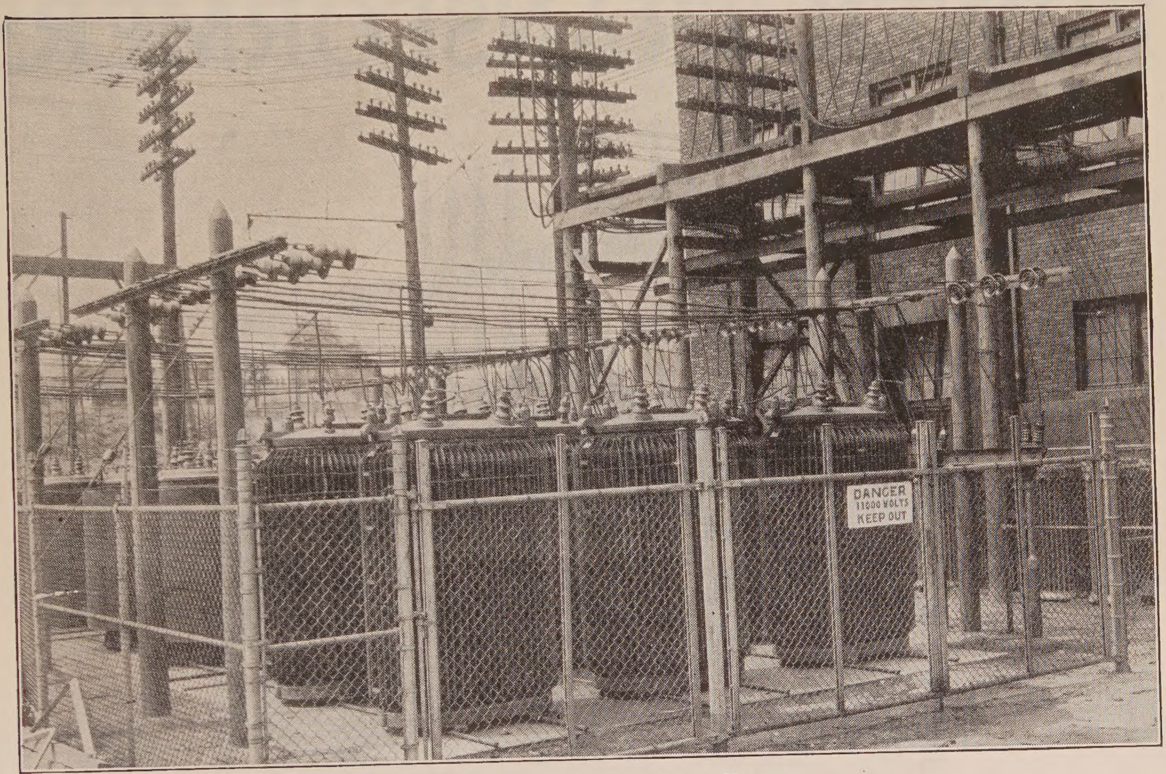

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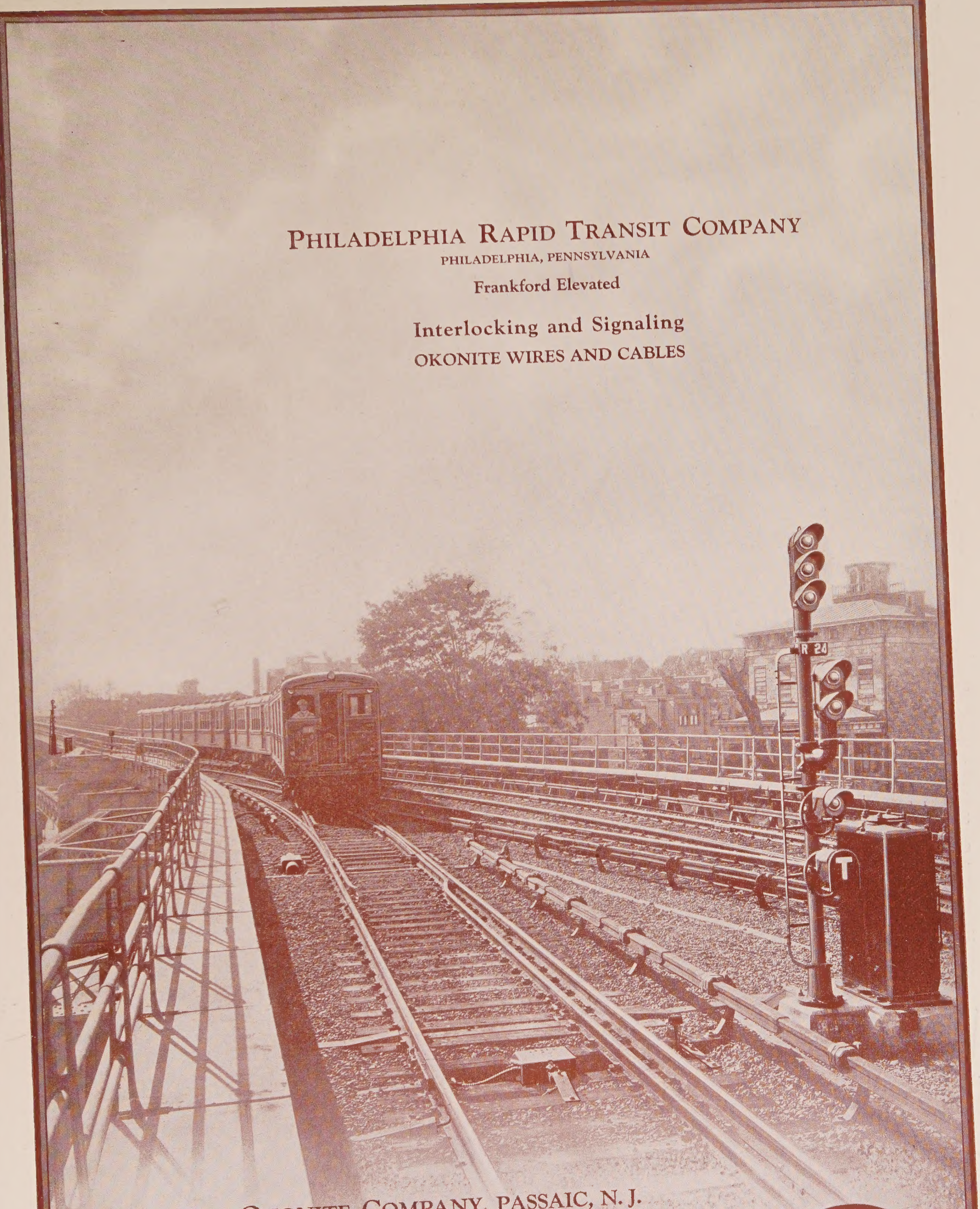
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